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The effects of conventional and interval training based exercise in knee rehabilitation.

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THE EFFECTS OF CONVENTIONAL AND INTERVAL TRAINING BASED EXERCISE IN KNEE REHABILITATION

by

Candice L. Mazer

A Thesis
Submitted to the Faculty of Graduate Studies
through the Faculty of
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of the Requirements for the Degree
of Master of Human Kinetics
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1982

ABSTRACT

An interval training based exercise program (Group 1), a progressive resistance exercise program (Group 2), and a home exercise program (Group 3) for rehabilitation of subjects after knee injury and surgery were compared.

Fifteen subjects were matched and assigned to one of the three groups. Isokinetic endurance and peak torque of quadriceps and hamstrings at 60 and 180 deg/sec were measured preoperatively or post-injury, after three weeks of treatment, and after six weeks of treatment. Subjects in the home program group were given exercises to perform at least three times weekly, and were directed to participate in physical activity as tolerated. All other subjects attended three treatment sessions/week for six weeks.

Significant differences between pretest injured and uninjured legs for quadriceps peak torque at both speeds were noted among all subjects ($p<.05$).

No significant differences among groups were found on posttest scores of the injured leg when pretest scores were used as the covariate ($p<.05$). No significant differences existed among groups for posttest differences between injured and uninjured legs. The posttest injured leg scores were significantly lower than the uninjured leg scores for quadriceps torque at 60 deg/sec (Groups 1 and 3) and at 180 deg/sec (Group 1). Exercise heart rates of subjects who performed interval training based exercise decreased significantly with

treatment.

Few changes were noted in scores of the uninjured leg over time or in uninjured leg scores among groups.

These results suggest that six weeks of rehabilitative exercise [illegible] not be sufficient to return quadriceps strength to normal levels. Results also suggest that home exercise programs may play an important role in rehabilitation and should not be overlooked. Interval training based exercise may help to augment cardiovascular fitness and should be explored further.

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CHAPTER I

Introduction

Musculoskeletal injury commonly results in decreased function of a limb and may necessitate a period of immobilization or decreased activity for healing to occur. In some instances, surgical intervention is required to facilitate a return to normal function. Prolonged disuse or decreased activity subsequent to injury and surgery cause disuse atrophy, decreased muscle strength, decreased anaerobic and aerobic capacities of muscle.

Rehabilitative exercise can play an important role in the return of an injured limb to normal function. Rehabilitation of musculoskeletal injuries has long been centered around strengthening atrophic muscles through performance of concentric progressive resistance and isometric exercise. These exercises impose an overload on the contractile elements of muscle, causing adaptations often measured as strength increases. The development of the isokinetic dynamometer has introduced an effective method of measuring and recording muscle torque generated through a continuous range of motion. Use of the isokinetic dynamometer has revealed noteable deficits at high angular velocities of contraction of knee musculature in postmenisectomy patients even after rehabilitation. These findings suggest that conventional rehabilitative exercise may be less than completely adequate in returning the injured limb to a normal level of function.

Interval training is a method of athletic training designed to enhance energy production for physical work through periods of alternating work and rest. Through manipulation of duration, intensity, frequency, and workload of work and rest intervals, overload is imposed on the alactic (ATP-CP), lactic (glycolytic) and/or oxidative (O2) systems. This overload appears to augment performance.

Interval training is commonly used by athletes whose programs include running, swimming and cycling. Application of the principles of interval training to rehabilitative exercise should be explored. Such use may introduce increased specificity of exercise, to overload both the metabolic and contractile elements of the muscle, and hasten return of completely normal function to the injured limb.

CHAPTER II

Review of Literature

The Effects of Immobilization and Inactivity on Skeletal Muscle

The effects of limb immobilization have been studied both in animals and in humans (Booth and Kelso, 1973; Booth, 1977; MacDougall et al., 1977; 1980). The present review will be limited to an examination of the effects of immobilization on human skeletal muscle.

Joint immobilization has been shown to produce significant disuse atrophy of involved muscles, as indicated either by decreased limb girth measurements (MacDougall et al., 1977; 1980; Patel et al. 1969) or by reduced leg volume (Sargeant and Davies, 1977; Davies and Sargeant, 1975). Maximal isometric and concentric isotonic contractions, as well as isokinetic peak torque of muscles acting upon immobilized joints, have all been reported to decrease significantly (MacDougall et al., 1977; 1980; Grimby et al., 1980).

Biochemical analyses of muscle biopsies from immobilized muscle have revealed various metabolic changes. Oxidative capacity has been shown to decrease (Eriksson, 1976; Costill et al., 1977). Intramuscular concentrations of creatine phosphate (CP), creatine and glycogen have also been reported to decrease (MacDougall et al., 1977).

While the number and percentage of each fiber type in muscle has been reported to remain constant with immobilization (MacDougall et al., 1980) significant decreases in both type I (slow twitch) and type

II (fast twitch) muscle fiber areas have been reported (MacDougall et al., 1980; Grimby et al., 1980; Sargeant et al., 1977). There is a controversy over which muscle fiber type demonstrates the greatest atrophy. MacDougall et al. (1980) reported greater decreases in type II fiber areas (in triceps brachii), whereas Sargeant et al. (1977) reported greater atrophy of type I fibers (in vastus lateralis).

Atrophic changes in skeletal muscle have also been noted in cases of long standing knee joint dysfunction. Edstrom (1970) found selective atrophy of type I fibers in patients with six month to four year histories of knee joint instability due to anterior cruciate insufficiency.

Joint injury, dysfunction, and surgery may all cause pain and effusion in affected joints. The effusion may play an important part in the development of subsequent muscle atrophy. Knee joint effusion has been reported to cause an inhibition of quadriceps femoris contraction, and hence, a type of disuse (deAndrade et al., 1965; Jayson and Dixon, 1970; Strafford, 1982). Joint capsule edema and sectioning of the joint capsule afferent innervation have been reported to cause inhibition of muscle contraction and thus may lead to disuse atrophy (Gardner, 1948). DeAndrade et al., (1965) demonstrated that edema, even before pain, could cause sufficient reflex inhibition of the muscle's afferent input to cause atrophy. In addition, pain inhibits the monosynaptic reflex to tonic motor units, while severe pain inhibits the monosynaptic reflex to both tonic and phasic motor units (Gydikov, 1976). Eriksson (1981) found evidence to support this proprioceptive influence of motor units. When an anaesthetic epidural (afferent) block was used on patients with postsurgical quadriceps dysfunction, integrated electromyographic activity increased more than ten fold. All of these symptoms may also contribute to patient inactivity. Prolonged inactivity has been reported to cause significant decreases in oxidative capacity of muscle, particularly in slow twitch fibers (Saltin and Rowell, 1980).

The Use of Arthroscopy

The introduction of arthroscopic investigation and arthroscopic surgery has dramatically altered diagnosis and treatment of knee joint dysfunction. These procedures can be carried out on an outpatient basis thus shortening hospital stay and reducing surgical costs. In addition, decreased postoperative swelling, decreased time on crutches, decreased rehabilitation time, decreased time to full activity, work, and sport have been noted (Pettrone, 1982; Guhl, 1979). A patient who had undergone a menisectomy via arthrotomy may have spent up to three weeks with the leg in a soft dressing, ambulated with crutches, and performed only isometric contractions of muscles of the affected leg before formal rehabilitation could begin. With arthroscopic partial menisectomies the patient can begin weightbearing as tolerated with crutches immediately after surgery and can begin full rehabilitation immediately after surgery. Where arthrotomy involves cutting the joint capsule, synovium, and the knee extensor mechanism and subsequent suturing, arthroscopy involves two to five insisions of six to twelve mm into the suprapatellar pouch and joint that seldom require sutures. "The polypuncture techniques combined with percutaneous intraarticular manipulation of the scope and tissue allow visualization and examination of the total joint" (Basset and Whipple, 1978), as well as additional surgical intervention, including partial menisectomy. Removal of only the segment of the meniscus that appears to be causing the knee problem leaves the patient with part of the meniscus that can continue to provide its important weightbearing function (O'Donoghue, 1980).

Rehabilitative and Strength Training Exercises

Rehabilitative exercises for the knee after injury and surgery have taken many forms. Most programs have stressed the development of muscle strength and have focused on strengthening exercises for muscles crossing the knee joint (Cassell, 1973). Exercise regimes have most commonly included: 1. isometric contractions; 2. concentric progressive resistance exercises (DeLorme, 1945; Zohn and Leach, 1964; O'Donoghue, 1976; Malone et al., 1980); 3. isokinetic exercise (Malone et al., 1980); and 4. cycling and bicycle ergometry. The latter have been included for development of endurance (O'Donoghue, 1976; Costill et al., 1977; Malone et al., 1980).

Campbell and Glenn (1979) examined muscle torque of patients who had undergone menisectomies five to fifteen months earlier, and who had participated in extensive rehabilitation programs that emphasized progressive resistance exercise. The authors reported similar peak torque measurements between legs at a slow speed of isokinetic contraction but significant differences in both knee extensors and flexors at high speed. These findings suggest a need for modification of rehabilitation programs to develop greater torque at high speeds of contraction through increased specificity of training.

In order to develop more specific rehabilitation techniques, one must first examine muscle strengthening techniques. Concentric progressive resistance weight training has been shown to effectively increase muscle strength (DeLorme, 1945). DeLorme developed the concept of 10 Repetitions Maximum, (10RM), the weight that an individual could move through a specified range of motion ten and only ten times. DeLorme initially advocated seven to ten sets of repetitions, performed against a weight that was to be increased through the workout so that the last set was performed against the 10RM resistance The 10RM was to be increased whenever weekly retests demonstrated that the subject could perform more than ten repetitions in one set. After further research, DeLorme and Watkins (1948) reported that three sets of repetitions , performed at one-half 10RM, three-quarters 10RM and at 10RM respectively, produced similar gains in muscle strength.

Scientists have since demonstrated that a range of sets, repetitions, and resistances could effectively strengthen muscle (Berger 1962a; 1962b; 1963; 1965). Hence, three sets of six to ten repetitions at 6RM to 10RM are now considered to be the most effective for muscle strengthening through concentric progressive resistance exercise. Recommendations in the literature for rest intervals between sets of exercises have varied from three minutes (Clark et al., 1954) to five and even ten minutes (Lamb, 1978). Clarke (1973) and Gilliam (1982) have found the most effective frequencies of strength training to be three to five times per week. Strength gains have been noted from programs of six to twelve weeks in duration (Berger, 1962a; 1963; 1965; O'Shea, 1966). However, strength at twelve weeks, was shown to be significantly greater than strength at six weeks (Berger, 1962a).

Eccentric progressive resistance exercise has also been shown to increase muscle strength (Komi and Buskirk, 1972; Johnson et al., 1976). While Komi et al. (1972) found greater gains with eccentric training than with concentric training, Johnson et al. (1976) found no difference between the two methods.

For isometric muscle strengthening exercise, a range of effective intensity, duration and frequency has been established. Daily maximal voluntary contractions of five to six seconds appear to be the most effective method of increasing isometric strength (Muller, 1962; Meyers, 1967).

Isometric exercises are easily performed and require little time and equipment. While some studies have found that isometric strength training was preferrable to concentric strength training after injury, many studies have indicated that there was little significant transfer of strength gain from isometric training to dynamic performance (Lindh, 1979). Knight et al. (1979) demonstrated that integrated electromyographic activity of all superficial muscles of the quadriceps femoris was greater during concentric resisted knee extension than during resisted straight leg raising, and thus suggested that the isotonic movement was preferrable for the purposes of muscle strengthening.

Isokinetic exercises have been shown to be effective in increasing muscle strength (Coyle et al., 1981; Pipes et al., 1975; MacDougall et al., 1980). Muscle strengthening exercise can be performed on an isokinetic device such as the Cybex II or Orthotron (Lumex, Inc.):

> "...the isokinetic dynamometer consists of an electromechanical device that keeps limb motion at a constant, preselected

> velocity. Force applied by the subject is met by an equal counter-force. The lever arm of the dynamometer is mechanically prevented from surpassing a preset and constant speed. Increased muscular output produces increased resistance rather than increased acceleration and the resistance is proportional to the dynamic tension produced in the muscle at every point in its range of shortening. Maximal force applied by the subject is met by a maximal resistance with the force being recorded externally as torque." (Barnes, 1980, p. 714).

In the Cybex II, an electrogoniometer and dual channel recorder provide continuous graphical recording of the torque throughout the range of motion. Validity and reliability of the measurements have been demonstrated (Moffroid et al., 1969; Alexander and Molnar, 1973; Mawdsley and Knapik, 1982).

Strength training has been reported to cause muscle hypertrophy reflected in increased muscle fiber area (MacDougall et al., 1980). Increased limb circumference after training however has not been reported consistently. O'Shea (1966) and MacDougall et al. (1977) found increased limb girth after strength training; Liberson and Asa (1959) found no significant increases. These results may reflect variations in thickness of subcutaneous fat and connective tissue and should lead one to minimize the reliability of girth measurements in assessing actual muscular hypertrophy.

A final consideration when examining muscle strengthening modalities is that of cross transfer of strength from the exercised to the unexercised, contralateral limb. Conflicting results have been reported in the literature. While Hellebrandt (1951), Darcus and Salter (1955) and Rasch and Morehead (1957) have demonstrated a cross transfer effect, Muller (1957) and Gardiner (1963) reported no evidence of such a contralateral strength increase.

Dominant versus Non Dominant Leg Strength

Normative data comparing leg strength of the dominant versus non dominant legs offer a range of findings in the literature. Goslin and Charteris (1979) defined the dominant leg as the one that generated the greatest torque. They studied thirty male and thirty female nonathletic university students. Quadriceps and hamstring peak torque at 30 deg/sec in the non dominant leg was 86.7% of the dominant in males and 81.2% of the dominant in females.

Patten Wyatt and Edwards (1981) defined dominant as the leg with which a subject would kick a ball. They reported that in a population of 50 nonathletic males, non dominant peak torque of quadriceps and hamstrings at 60 deg/sec was 97% of the dominant torque and that at 180 deg/sec the non dominant was 97% and 98% of the dominant for these muscle groups. They found that in 50 nonathletic females, non dominant quadriceps and hamstrings peak torque at 60 deg/sec and 180 deg/sec were 99%, 99%, 99% and 97% of the dominant leg respectively.

Interval Training

Interval training is a type of athletic training that involves performance of a series of bouts of exercise interspersed with rests or relief intervals. The intermittent nature of this work enables the subject to perform more work before the onset of fatigue than would be possible if the work were continuous (Mathews and Fox, 1976). Interval training has been used to train the alactic system (ATP-CP), lactic system (glycolytic), oxidative system (TCA-ETS) or a combination of these systems through overloading the appropriate system(s) (Hollering et al., 1971; Fox et al., 1977; Eddy et al., 1977; Ready, 1977). Overload can be imposed through manipulation of: rate of work; number of repetitions and sets per workout; duration of relief interval; type of activity during relief interval; and frequency of training per week (Fox and Mathews, 1974).

Strength training exercise is typically performed in intervals of less than thirty seconds, using the ATP-CP system. Thus, interval training for the ATP-CP system is of particular interest for the present study. During the first ten to thirty seconds of strenuous exercise, energy for muscular contraction is supplied primarily through the ATP-CP system (Margaria, 1964; 1967; Margaria et al., 1969; Wenger and Reed, 1976; Karlsson et al., 1975). Creatine phosphate (CP) depletion is proportional to the intensity and duration of dynamic work (Hultman et al., 1967). Repletion of endogenous ATP and CP stores occurs through the oxidative system (Astrand and Rodahl, 1977; Fox, 1973). In thirty seconds of rest after strenuous exercise, fifty percent of the endogenous ATP and CP is restored (Margaria, 1967). In two minutes of rest, all stores of ATP and CP are restored (Hultman et al., 1967; Fox, 1973). Fox and Mathews (1974) have recommended a work to rest ratio of 1:3 in order to overload recovery of this alactic system.

An interval training based rehabilitative exercise program may offer a method of stimulating both the metabolic and contractile systems of the muscle which are affected after injury. Such a program may hasten the return of the injured limb to a normal level of function.

Rating of Perceived Exertion

Psychophysical scales of rating of perceived exertion (RPE) have been shown to link an individual's perception of physical work performed with the physiological responses of her/his body to work (Borg, 1973; Borg and Noble, 1974). RPE has been shown to provide information about exertion, fatigue, pain, discomfort, and other variables of work performed in physical therapy (Borg and Noble, 1974). RPE scales have been tested with a variety of exercise protocols; their validity and reliability have been demonstratedBorg and Noble, 1974.

Purpose:

The purpose of the present study was to evaluate and compare the effects of three programs of rehabilitative exercise after arthroscopic surgery or ligamentous sprain of the knee: 1. supervised interval training based bicycle ergometry and progressive resistance exercise; 2. supervised untimed progressive resistance exercise; and 3. unsupervised exercise and activity. Peak torque of knee musculature at low and high speeds of isokinetic contraction and isokinetic endurance were examined in the injured leg preoperatively and postoperatively before and after six weeks of treatment. These variables were examined in the uninjured leg before treatment, after three and six weeks of treatment. Statistical analyses were used to demonstrated whether: 1. the programs differed in their ability to promote the return of normal function to the postoperative leg; 2. the injured leg was weaker than the uninjured leg preoperatively and posttreatment; 3. strength changes occured in the uninjured leg over the time of the experiment.

Null Hypotheses:

Ho1: There is no significant difference in peak torque between the uninjured and injured legs before treatment.

PT uninjured = PT injured

Ho2: There is no significant difference in endurance between the uninjured and injured legs before treatment.

End uninjured = End injured

Ho3: There is no significant difference in peak torque among the three groups after treatment.

PT1 = PT2 = PT3

Ho4: There is no significant difference in endurance among the three groups after treatment.

End1 = End2 = End3

Ho5: There is no significant difference in peak torque difference scores among the three groups after treatment.

PT Diff1 = PT Diff2 = PT Diff3

Ho6: There is no significant difference in endurance difference scores among the three groups after treatment.

EDiff1 = EDiff2 = EDiff3

Ho7: There is no significant difference in peak torque of the uninjured leg at zero, three and six weeks of treatment.

PT at 0 = PT at 3 = PT at 6

Ho8: There is no significant difference in endurance of the uninjured leg at zero, three and six weeks of treatment.

End at 0 = End at 3 = End at 6

Ho9: There is no significant difference in ratings of perceived exertion of exercise between the two supervised exercise groups.

RPE1 = RPE2

CHAPTER III

Methodology

Clarification of Terms

a. Knee extension represented an active range of motion of the quadriceps from approximately 90 degrees of flexion to full extension.

b. Knee flexion represented an active range of motion of the hamstrings from full extension to approximately 90 degrees of flexion.

c. Peak torque of both knee extensors and flexors were measured at 60 deg/sec and at 180 deg/sec.

d. Endurance was measured on both knee extensors and knee flexors at 180 deg/sec.

e. Difference scores were equal to the peak torque or endurance measurements of the uninjured leg minus the peak torque or endurance measurements of the postoperative leg.

f. 10RM represented 10 repetitions maximum, the weight that a subject could move through a specified range of motion 10 and only 10 times. In this study, 10RM* was used to refer to the weight that a subject could contract against between 9 and 12 times.

g. For subjects with ligament sprains, pretest scores of the uninjured leg were assigned to the injured leg as pretest scores.

h. Pretest scores were derived from the initial (preoperative) testing session.

i. Week 3 Scores were derived from the test sessions held after three weeks of treatment.

j. Posttest scores were derived from the final test session, after subjects had completed six weeks of treatment.

This study was conducted in several stages: subject selection, evaluation, treatment, reevaluation and analysis. All subjects were evaluated preoperatively, postoperatively before treatment, after three weeks of treatment, and after six weeks of treatment.

Subject Selection

The goal of subject selection was to include individuals who had meniscal derangement in one knee and who had undergone subsequent arthroscopic investigation and partial menisectomy. Such individuals could begin rehabilitation within one week of surgery with a minimum of postoperative pain and joint effusion. The population from which subjects were drawn was later enlarged to include individuals who had suffered sprains of knee ligaments in order to augment the number of subjects in the study.

All persons considered for participation in this study were under the care of an orthopaedic surgeon for knee joint dysfunction. Those considered had no known history of pathology in the uninjured knee. A summary of subject selection is found in Table 1. The investigator reviewed patient histories of all those scheduled for surgery and submitted to the physician a list of patients who seemed to have no medical contraindications to participation in a six week rehabilitative exercise program or in endurance activities. Upon approval by the

TABLE 1

SUMMARY OF SUBJECT SELECTION PROCESS

Subjects with possible meniscal derangements initially contacted	34
Subjects who declined participation	3
Subject who did not attend pretest session	1
Subjects who cancelled surgery	1
Subjects who declined participation during pretest appointment	1
Subjects screened out during surgery	12
Subjects who dropped out after surgery	4
Total subjects with meniscal derangements	12
Subjects with ligamentous sprains, included	3
TOTAL SUBJECTS INCLUDED IN STUDY	15

physician, the investigator contacted all potential subjects, explained the nature of the study and asked them to consider participation in the study. Three subjects who had suffered ligamentous sprains were also contacted and agreed to participate in the study. Thirty-four patients with possible meniscal lesions expressed interest, and appointments were made for preoperative testing during the week prior to her/his surgery. Three patients who were contacted chose not to participate in the study. At the time of the first appointment for each potential subject, the testing and rehabilitation methods were explained in detail by the investigator. Thirty of the thirty-one subjects agreed to participate and were asked to sign informed consent forms (Appendix B). Testing on the Cybex II was then carried out. One subject who had expressed interest in participating failed to attend preoperative testing sessions on three occasions and was eliminated from further consideration. One subject who was tested cancelled his surgery, and was therefore excluded from consideration.

During the arthroscopic examination the surgeon visualized the tibiofemoral and, in some cases, the patellofemoral joints and offered differential diagnoses. Twelve subjects were screened out at this time due to various pathologies in the knee. Of the remaining sixteen subjects, nine had a torn medial or lateral meniscus; six had a torn medial or lateral meniscus with anterior cruciate insufficiency. Eleven of the twelve subjects underwent partial menisectomies; one subject had suffered a radial tear in the lateral meniscus that effectively separated the anterior and posterior segments. The physician felt that no further surgical intervention was required. Of the subjects with ligamentous sprains, two individuals had sustained grade two medial or lateral collateral ligament sprains. The final subject had suffered a ligament sprain and had undergone a diagnostic arthroscopic investigation which revealed a lateral collateral ligament sprain and a 15% tear of the anterior cruciate ligament.

Subject Attrition

Four subjects were excluded from the study at various stages after surgery. Two attended only one treatment session. One subject continued treatment for three weeks and then discontinued treatment. One subject was unable to perform the set of exercises because of knee pain and therefore was excluded from the study. He was placed on a modified treatment program and continued therapy for seven weeks.

Measurement Procedures

Upon entering the laboratory for the first time, each subject was familiarized with the testing equipment and procedures.

A. Determination of Peak Torque

The chair back of the Cybex II was fixed at a 110 degree angle. The subject's position on the testing apparatus was adjusted to allow at least 90 degrees of knee flexion. A strap was then placed over the proximal thigh of the leg to be tested. The subject's lateral femoral condyle of the uninjured leg was aligned with the axis of rotation of the isokinetic dynamometer; the subject's lower leg, just proximal to the lateral malleolus, was placed behind the ankle cuff of the arm of the dynamometer so that the knee rested at approximately 90 degrees of flexion. The subject was asked to hold the hand grips on each side of the chair for stabilization of the trunk.

The dynamometer was set at 60 deg/sec, the damping was set at '2' and the paper speed was set appropriately. The subject was asked to perform ten reciprocal contractions of the quadriceps femoris and hamstring muscle groups increasing in intensity so that the last three contractions were maximal. This procedure was designed to familiarize the subject with the machine. After a three minute rest, the subject was instructed to kick up and kick down as hard and fast as possible four times, performing maximal voluntary contractions. This procedure was repeated twice more, with three minute rests in between the sets of contractions. Verbal encouragement was given to the subject during each contraction. The subject's lateral femoral condlye of the injured leg was then aligned with the axis of rotation of the dynamometer and the subject performed the same procedures on this leg. Again, verbal encouragement was given to the subject during each maximal contraction.

This procedure for determination of peak torque was repeated at the setting of 180 deg/sec, first on the uninjured and then on the injured leg. The mean of the highest score in each set was used as the peak torque for each muscle group at each speed.

B. Determination of Endurance Scores

Each subject performed a series of thirty-one continuous, maximal, reciprocal contractions at 180 deg/sec. The subject assumed the testing position described above with the uninjured leg aligned for contraction. The subject was instructed to kick the leg up and down as fast as possible thirty-one times. Verbal encouragement was given during the procedure. The investigator monitored the torque and range of motion on the dual channel recorder to ensure that the subject was moving the limb through the full available range of motion and instructed the subject to bend or straighten the limb more fully if necessary. This procedure was repeated on the injured leg. The subject was asked to perform a warm down consisting of stretching and walking after the test.

An endurance score was calculated as follows:

$$\frac{\begin{bmatrix}\text{Peak Torque of}\\ \text{Contractions 2 to 5}\end{bmatrix} - \begin{bmatrix}\text{Peak Torque of}\\ \text{Contractions 28 to 31}\end{bmatrix}}{\left[\text{Peak Torque of Contractions 2 to 5}\right]} \quad \text{X} \;\; 100$$

The first contraction of each muscle group was considered a warm up and was thus disregarded in this calculation.

C. Postoperative or Postinjury Treatment Given To All Subjects

Subjects who met the medical and operative criteria for participation in the study returned to the laboratory one to four days postoperatively or postinjury. All treatment, supervision and timing were performed by the investigator. During the first treatment, each subject was given a regime of ice for the knee, isometric quadriceps and hamstring contractions, active knee range of motion and stretching for lower limb musculature. Each subject was asked to repeat this treatment twice daily at home until the day of postoperative testing, four to six days later.

D. Group Assignment and Measurement

Protocols for determination of peak torque and endurance were repeated on the postoperative leg only. Initially, the investigator randomly assigned each subject to one of three experimental groups by drawing numbers out of a hat. The investigator attempted to match subsequent subjects according to injury, sex and age with the initial subjects, assigning the second matched subject randomly to one of the two remaining groups and the third matched subject to the last group. Subjects with meniscal derangements underwent reevaluation of peak torque and endurance of the injured leg four to six days after surgery. The protocols for determination of the scores were identical with the pretest protocols described earlier. At this point, each subject was ready to participate in the treatment phase of this study.

After three weeks of treatment, each subject underwent reevaluation of peak torque and endurance of only the uninjured leg, again following the pretst protocols.

At the end of six weeks of treatment subjects in Groups 1 and 2 returned to the laboratory for reevaluation of peak torque and endurance of both legs. Subjects in Group 3 returned for testing 7 to 7.5 weeks after their pretests. While attempts were made to test Group 3 after six weeks, none of the subjects were able to return on the six week dates. Protocols were identical to those used for the pretest. The three subjects who had suffered sprains underwent testing on both legs approximately one week postinjury. After three weeks they underwent testing on the uninjured leg and after six weeks they underwent testing on both legs. Thus these subjects were tested only twice on the injured leg. Because these subjects had no problem previous to their injuries, pretest scores from the uninjured legs were assigned to their injured legs. Patten Wyatt and Edwards (1981) found that differences in peak torque between the dominant and non dominant legs were less than 4% for quadriceps and hamstrings at 60 and 180 deg/sec, therefore it was assumed that the scores for the uninjured leg could be used to represent scores for the injured leg prior to injury.

Postoperative test results (on the injured leg) were affected by the amount of pain and effusion the subjects experienced. Because symptoms varied greatly from subject to subject these postoperative scores were eliminated from consideration.

Treatment

1. Interval Bicycle Ergometery Supervised Exercise Group (Group 1)

On the first day of experimental treatment (after postoperative testing) each subject assigned to the interval group performed sets of hamstring contractions to determine the 10RM* of the postoperative leg. The subject lay in a prone position on the exercise table with the knee in extension and the ankle cuff of the equipment resting comfortably on the posterior surface of the lower leg, proximal to the lateral malleolus. A strap was placed around the subject's buttocks and the exercise table to stabilize the lower back. The investigator applied weights to the equipment and asked the subject to bend the knee as many times as possible in twenty seconds. If the subject was able to move the resistance through the range of motion more than ten times, the investigator increased the weight and, after a three minute rest, asked the subject to repeat the series of contractions. If the subject was unable to perform ten repetitions, the investigator decreased the weight and asked the subject to repeat the series of contractions. This was repeated up to three times. In this manner a "20 second-10RM*" was established.

Each subject performed one exercise on the Monark bicycle

ergometer. The height of the seat of the ergometer was adjusted so that the knee was flexed 10 degrees when the pedal was at the lowest point on the revolution. The subject pedalled with the postoperative leg only. During weeks one, and four to six, the subjects pedalled at a rate of 60 RPM. During weeks two and three the subjects pedalled at a rate of 69 RPM. A metronome was used to ensure that the rate of pedalling remained constant. The forefoot was held firmly onto the pedal with adhesive tape. The subject performed timed fifteen second work intervals (repetitions) as indicated in Table 2.
Heart rate was monitored by the investigator at the end of each repetition, using a ten second count of the radial pulse.

Initially during each set, the pendulum setting on the ergometer was 4.9 newtons for the first repetition, 9.8 newtons for the second and third repetitions, and was increased by 4.9 newtons for each successive repetition in the set either until she/he could not perform at a higher workload, or until the subject had reached 75 to 80% of the individuals's maximum predicted heart rate. At this point, the pendulum setting was held constant for the remaining repetitions of the set. During the six weeks of treatment, the initial pendulum setting was increased as tolerated. The duplication of the pendulum setting of the second repetition was eliminated by the second week of the program. If the subject's heart rate exceeded that stated above, the pendulum setting was decreased for the next repetition.

Each subject also performed three sets of ten repetitions of concentric resisted hamstring contractions on the exercise table at the 10RM* resistance. Each set was performed in twenty seconds and rest intervals between sets followed the guidelines listed in Table 3.

TABLE 2

WORK TO REST RATIOS FOR GROUP 1 BICYCLE ERGOMETRY

Week	Repetitions/ Set	Sets/ Workout	Work:Rest Ratio	Rest Interval Between Repetitions (Seconds)	Rest Interval Between Sets (Minutes)
1	8	2	1:4	60	4 to 7
2	9	3	1:4	60	4 to 7
3	9	3	1:3	45	4 to 7
4	9	4	1:3	45	4 to 7
5	9	3	1:3	45	4 to 7
6	9	3	1:3	45	4 to 7

TABLE 3

WORK TO REST RATIOS FOR GROUP 1 HAMSTRING CONTRACTIONS

Week	Work:Rest Ratio	Rest Interval (Seconds)
1	1:6	120
2	1:5	100
3	1:4	80
4	1:3	60
5	1:3	60
6	1:3	60

Whenever the subject was able to perform more than ten repetitions in a set, the resistance was increased to a new 10RM* during the treatment.

At the end of each exercise session the subject performed lower limb stretches and calf raises as listed in Table 4. The investigator then held up a card with a scale of rate of perceived exertion (Table 5) and asked the subject to point to the number that best indicated how she/he felt about the exercise session as a whole. The investigator recorded the resistance used, and the RPE.

Each subject's maximum heart rate was determined using the formula: Maximum heart rate = 220 - Subject's age (Fox and Mathews, 1981). The heart rate was held to a maximum of 75-80% of the maximum heart rate. After the final testing session for each subject in Group 1, each subject returned to the laboratory to complete two sets of bicycle ergometry that duplicated sets performed during the first two weeks of treatment. Subjects were asked to perform no extra exercise between treatments.

2. Untimed Concentric Progressive Resistance Supervised Group (Group 2)

Each subject assigned to the untimed progressive resistance group underwent a procedure to determine the 10RM* resistance for concentric quadriceps and hamstring contractions of the injured leg on the first day of treatment. After a warm up consisting of three minutes of bicycle ergometry at a workload of 150 kilogram meters/minute, the subject sat on the exercise table with the knee at approximately 90 degrees of flexion and the ankle cuff of the equipment resting comfortably on the anterior surface of the lower leg, proximal to the lateral malleolus. The untimed 10RM* for quadriceps of the injured leg was established using the protocol for 10RM* determination described

TABLE 4

ADDITIONAL EXERCISES GIVEN TO GROUPS 1 AND 2

1. Quadriceps stretch
2. Hamstring stretch
3. Tensor fascia lata stretch
4. Lower back stretch
5. Groin stretch
6. Calf raises using resistance

TABLE 5

RATES OF PERCEIVED EXERTION (BORG, 1982)

0	Nothing at all
.5	Very, very little (just noticeable)
1	Very light
2	Light (weak)
3	Moderate
4	Somewhat heavy
5	Heavy (strong)
6	
7	Very Heavy
8	
9	
10	Very, very heavy (almost max)

for Group 1. The subject then lay in a prone position on the exercise table, and the untimed hamstring 10RM* was established following the 10RM* protocol described for Group 1.

The remaining seventeen treatments consisted of three sets of repetitions of concentric resisted quadriceps and hamstring contractions at the 10RM* resistance plus exercises listed in Table 4. Each subject was instructed that rest periods between sets had to be more than three minutes and that each set of contractions had to take longer than twenty-five seconds to complete. Beyond these time specifications the subject was at liberty to exercise at a comfortable pace. Whenever the subject could perform more than 10* repetitions in a set, the resistance was increased during the treatment so that a new 10RM* was established.

Each exercise session was completed in the same manner as those for Group 1. Subjects were asked to perform no extra exercise between treatments.

3. Unsupervised Exercise and Activity Group (Group 3)

Each subject received instructions in and a demonstration of a set of exercises for the postoperative leg (Table 6) and was asked to perform the exercises at least three times weekly for six weeks. Only subjects of Group 3 were asked to keep a written record of exercise performance, problems that arose with the postoperative leg and all physical activities other than activities of daily living. In addition, only subjects of this group were instructed to exercise the uninjured leg if they desired to do so. Subjects were, however, asked to make a note of such activity in their diaries.

TABLE 6

GROUP 3 PROGRAM OF HOME EXERCISES

1. Isometric quadriceps contractions with the knee in full extension with the knee bent 30, 60, and 90 degrees
2. 6-10 second isometric hamstring contractions with the knee in full extension, bent 30, 60 and 90 degrees.
3. Straight leg raises using resistance
4. Hamstring stretches
5. Knee range of motion
6. Hip abduction using resistance
7. Hamstring curls using resistance
8. Calf stretches
9. Groin stretches
10. Quadriceps stretches
11. Tensor fascia lata stretches
12 Calf raises using resistance
13. Leg presses against resistance

Calibration of Equipment

The Cybex II was calibrated biweekly according to the method suggested by Lumex Inc.. The bicycle ergometer was calibrated weekly.

Conversion of Data

All data reflecting quadriceps and hamstring torque at 60 or 180 deg/sec were converted from foot pounds to newton meters. These data were corrected to reflect torque outputs independent of gravity and the length and mass of the lower leg (see Appendix C for conversion and correction equations).

Statistical Analyses

Dependent samples t tests were performed on pretest peak torque and endurance scores for both legs. Analyses of variance and covariance for unbalanced data were performed on the posttest data from the injured leg. Pretest scores were used as the covariate for the latter analyses. Analyses of variance for unbalanced data were also used to analyse scores that reflected differences between posttest scores of the injured and uninjured legs. One way analyses of variance with repeated measures were performed on peak torque and endurance scores of the uninjured leg at zero, three and six weeks. Any significant differences noted through the ANOVAs with repeated measures were further analysed using the Newman-Keuls' post hoc procedure. Significant differences noted for other ANOVAs were assessed using the Duncan Multiple Range test. Data reflecting the rates of perceived exertion for each group were treated with t tests for independent samples. Posttest scores for the injured and uninjured legs and heart rate data were assessed using dependent samples t tests. The level of significance for all statistical analyses was $p<.05$.

CHAPTER IV

Results

The physical characteristics and knee pathologies of the subjects are shown in Table 7. Group mean muscle torques of the injured and uninjured legs expressed in newton meters are presented in Tables 8 and 10. Group mean endurance scores for both legs are presented in Tables 11 and 13. Posttest group least square means for the injured leg are presented in Tables 9 and 12. Least square means represented: a. means adjusted to take into consideration the covariate and b. estimated means if the groups had been balanced. Group mean muscle torques expressed in foot pounds are presented in Appendicies N and O. Group mean posttest difference scores are presented in Tables 14 and 15.

Dependent samples t tests were used to compare pretest data of the injured and uninjured legs (Table 16). A significant difference was noted for quadriceps torque at 60 degrees/ second for Group 1 and for quadriceps torque at 180 degrees/ second for Group 3 ($p<.05$). When all pretest differences between legs were examined together (n=15), significant differences were noted in quadriceps peak torque at both speeds ($p<.05$). When the scores of the three subjects with sprains were eliminated, similar significant differences were noted. Similar analysis of data of subjects with anterior cruciate ligament insufficiency (n=6) also revealed significant differences in quadriceps torque at 60 and 180 deg/sec ($p<.05$, Table 17).

TABLE 7

PHYSICAL CHARACTERISTICS OF SUBJECTS

Group 1 (Interval)   Mean Age: 34.4 years

Subject 1   Age: 19
Sex: male
Diagnosis: lateral collateral ligament and anterior cruciate ligament sprain, left knee
Operative Procedure: arthroscopy
Testing for study: postinjury, (postoperatively)
Dominant leg: right
Onset of Symptoms: 1 week

Subject 2   Age: 36
Sex: male
Diagnosis: torn medial meniscus, right knee
Operative Procedure: arthroscopy, partial medial menisectomy
Dominant Leg: right
Onset of Symptoms: 4 years

Subject 3   Age: 24
Sex: female
Diagnosis: chronic anterior cruciate insufficiency, torn medial and lateral menisci, left knee
Operative Procedure: Examination under anaesthesia, partial medial menisectomy
Dominant leg: left
Onset of Symptoms: 1.25 years

Subject 4   Age: 42
Sex: male
Diagnosis: torn lateral meniscus, chrondromalacia patella, left knee
Operative Procedure: arthroscopy, patial lateral menisectomy
Dominant Leg: right

Onset of Symptoms: 4 years

Subject 5   Age: 51
Sex: male
Diagnosis: torn medial meniscus, left knee
Operative Procedure: arthroscopy, partial medial menisectomy
Dominant Leg: right
Onset of Symptoms: 2 months

TABLE 7 (continued)

GROUP 2 (Progressive Resistance) Mean Age: 24.75 years

Subject 6 Age: 47
Sex: male
Diagnosis: chronic anterior cruciate insufficiency, torn medial meniscus, right knee
Operative Procedure: examination under anaesthetic, arthroscopy, partial medial menisectomy
Dominant Leg: right
Onset of Symptoms: 1.5 years

Subject 7 Age: 20
Sex: female
Diagnosis: chronic anterior cruciate ligament insufficiency, torn medial meniscus, degenerative articular cartilage changes, lateral compartment,torn lateral meniscus
Operative Procedure: examination under anaesthetic, arthroscopy, partial medial menisectomy
Dominant Leg: right
Onset of Symptoms: 4.25 years

Subject 8 Age: 15
Sex: male
Diagnosis: Grade 2+ sprain, medial collateral ligament, left knee
Operative Procedure: None
Testing For Study: postinjury
Dominant Leg: right
Onset of Symptoms: 1 week

Subject 9 Age: 17
Sex: male
Diagnosis: torn lateral mensicus, right knee
Operative Procedure: arthroscopy
Dominant leg: right
Onset of Symptoms: 3 years

GROUP 3 (Home Program) Mean Age: 26.5 years

Subject 10 Age: 20
Sex: female
Diagnosis: chronic anterior cruciate ligament insufficiency, torn lateral meniscus, left knee .
Operative Procedure: examination under anaesthetic, arthroscopy, partial lateral menisectomy
Dominant Leg: right
Onset of Symptoms: 2 years

Subject 11 Age: 32

TABLE 7 (continued)

Sex: male
Diagnosis: chronic anterior cruciate ligament insufficiency, torn medial meniscus, left knee
Operative Procedure: examination under anaesthetic, arthroscopy, partial medial menisectomy
Dominant Leg: right
Onset of Symptoms: 6 months

Subject 12 Age: 24
Sex: male
Diagnosis: Grade 2 lateral collateral ligament sprain, right knee
Operative Procedure: none
Testing for study: postinjury
Dominant Leg: left
Onset of Symptoms: 1 week

Subject 13 Age: 37
Sex: male
Diagnosis: torn medial meniscus, right knee
Operative Procedure: arthroscopy, partial medial menisectomy
Dominant Leg: left
Onset of Symptoms: 2 months

Subject 14 Age: 22
Sex: male
Diagnosis: torn medial meniscus, right knee
Operative Procedure: arthroscopy, partial medial menisectomy
Dominant Leg: left
Onset of Symptoms: 5 years

Subject 15 Age: 25
Sex: male
Diagnosis: chronic anterior cruciate ligament insufficiency, torn medial meniscus, left knee
Operative Procedure: examination under anaesthetic, arthroscopy, partial medial menisectomy
Dominant leg: left
Onset of Symptoms: 1 year

TABLE 8

MEAN PEAK TORQUE OF THE INJURED LEG ± SEM (NEWTON METERS) *

Variable	Group 1	Group 2	Group 3
PREQ60B	199.78 ± 39.02	173.12 ± 19.75	239.65 ± 22.12
POSQ60B	188.07 ± 26.20	175.48 ± 16.22	228.26 ± 24.70
PREQ180B	138.57 ± 24.44	126.45 ± 14.91	155.31 ± 15.62
POSQ180B	138.09 ± 19.03	132.45 ± 14.50	169.47 ± 18.42
PREH60B	109.87 ± 22.46	91.15 ± 7.44	123.62 ± 9.54
POSH60B	120.56 ± 20.72	113.69 ± 11.39	129.89 ± 17.15
PREH180B	84.09 ± 15.26	69.17 ± 3.52	97.43 ± 8.57
POSH180B	90.89 ± 12.78	82.07 ± 9.53	105.69 ± 12.69

TABLE 9

POSTTEST-LEAST SQUARE MEAN SCORES FOR PEAK TORQUE OF THE INJURED LEG ± SEM (NEWTON METERS) *

Variable	Group 1	Group 2	Group 3
POSQ60B	194.18 ± 13.86	200.35 ± 16.20	206.30 ± 13.32
POSQ180B	140.79 ± 10.19	144.93 ± 11.63	158.67 ± 9.51
POSH60B	120.99 ± 10.11	132.14 ± 11.91	116.65 ± 9.58
POSH180B	92.12 ± 7.42	97.51 ± 8.90	94.22 ± 7.17

* Key to Abbreviations is found in Appendix A

TABLE 10

MEAN PEAK TORQUE OF THE UNINJURED LEG ± SEM (NEWTON METERS) **

Variable	Group 1	Group 2	Group 3
PREQ60G	232.39 ± 29.21	212.31 ± 21.26	263.24 ± 24.72
W3Q60G	231.52 ± 27.99	202.06 ± 19.17	262.06 ± 21.59
POSQ60G	236.73 ± 26.75	205.34 ± 20.56	258.24 ± 21.90
PREQ180G	154.55 ± 18.35	142.06 ± 12.67	176.02 ± 15.87
W3Q180G	168.70 ± 19.76	151.53 ± 10.68	181.65 ± 17.30
POSQ180G	165.21 ± 19.94	147.42 ± 12.84	183.42 ± 19.71
PREH60G	116.30 ± 17.86	99.37 ± 6.50	130.83 ± 8.21
W3H60G	122.78 ± 20.04	107.63 ± 7.23	144.86 ± 13.07
POSH60G	125.59 ± 18.45	114.66 ± 9.72	140.02 ± 14.92
PREH180G	87.47 ± 13.90	76.11 ± 2.79	90.88 ± 7.67
W3H180G	92.79 ± 14.47	80.64 ± 6.42	109.47 ± 11.55
POSH180G	89.18 ± 14.19	85.39 ± 6.80	108.42 ± 11.53

TABLE 11

MEAN ENDURANCE SCORES FOR THE INJURED LEG ± SEM (%) * **

Variable	Group 1	Group 2	Group 3
PREQBEND	44.93 ± 6.92	45.23 ± 6.52	52.71 ± 2.40
POSQBEND	37.30 ± 5.92	39.07 ± 5.17	51.15 ± 2.78
PREHBEND	27.90 ± 2.81	23.20 ± 4.08	34.91 ± 5.75
POSHBEND	36.21 ± 5.37	30.14 ± 9.77	36.25 ± 3.59

* Endurance Score = [(Σ PT of contractions 2 to 5) − (Σ PT of contractions 28 to 31)] ÷ [Σ (PT of contractions 2 to 5)] X 100

** Key to Abbreviations is found in Appendix A

TABLE 12

POSTTEST LEAST SQUARE MEANS FOR ENDURANCE SCORES OF THE INJURED LEG ± SEM (NEWTON METERS) * **

Variable	Group 1	Group 2	Group 3
POSQBEND	39.54 ± 2.88	41.10 ± 3.21	47.93 ± 2.69
POSHBEND	37.81 ± 5.47	32.17 ± 6.14	33.57 ± 5.14

TABLE 13

MEAN ENDURANCE SCORES OF THE UNINJURED LEG ± SEM (%) * **

Variable	Group 1	Group 2	Group 3
PREQGEND	44.76 ± 6.91	40.71 ± 4.01	53.28 ± 2.89
W3QGEND	48.50 ± 2.36	33.74 ± 6.67	34.39 ± 5.23
POSQGEND	50.13 ± 2.20	48.98 ± 4.55	54.56 ± 2.34
PREHGEND	28.46 ± 5.78	34.12 ± 2.35	40.36 ± 1.34
W3QGEND	33.13 ± 2.58	46.40 ± 2.13	55.22 ± 3.45
POSHGEND	30.79 ± 5.75	37.11 ± 6.85	38.29 ± 2.42

* Endurance Score = [(Σ PT of contractions 2 to 5) − (Σ PT of contractions 28 to 31)] ÷ [Σ (PT of contractions 2 to 5)] X 100

** Key to Abbreviations is found in Appendix A

TABLE 14

MEAN PEAK TORQUE DIFFERENCE SCORES COMPARING INJURED VS UNINJURED LEGS ± SEM (NEWTON METERS) * ** (WITH SCORES EXPRESSED AS PERCENTAGES OF THE UNINJURED LEG ± SEM)

VARIABLE	GROUP 1	GROUP 2	GROUP 3
Q60DIF	48.66 ± 2.57 (21.70 ± 2.94)	29.86 ± 23.18 (12.44 ± 10.01)	29.98 ± 11.14 (12.31 ± 4.46)
Q180DIF	27.12 ± 2.36 (17.12 ± 2.02)	14.98 ± 7.68 (10.17 ± 4.81)	13.96 ± 7.10 (7.26 ± 3.42)
H60DIF	5.02 ± 4.71 (5.69 ± 4.65)	0.97 ± 4.47 (1.12 ± 4.33)	10.13 ± 4.94 (8.44 ± 3.86)
H180DIF	1.71 ± 2.21 (3.69 ± 3.44)	3.32 ± 3.56 (4.63 ± 4.34)	2.74 ± 5.63 (2.79 ± 4.60)

TABLE 15

MEAN ENDURANCE DIFFERENCE SCORES COMPARING INJURED VS UNINJURED LEGS(%) ± SEM * ** (EXPRESSED AS PERCENTAGES OF THE UNINJURED LEG ± SEM)

Variable	Group 1	Group 2	Group 3
QEND	12.83 ± 4.17 (26.89 ± 9.89)	7.33 ± 3.21 (16.73 ± 7.44)	4.07 ± 2.34 (7.42 ± 2.34)
HEND	-5.43 ± 4.04 (35.01 ± 27.38)	6.97 ± 6.26 (20.72 ± 14.10)	2.03 ± 3.02 (5.10 ± 7.65)

* Difference Score = Endurance Score of uninjured leg - Endurance score of the injured leg

Difference Score expressed as a Percentage = Endurance Score ÷ Endurance Score of the uninjured leg X 100

** Key to Abbreviations is found in Appendix A

TABLE 16

DEPENDENT SAMPLES t TESTS ON PRETEST SCORES OF INJURED VS UNINJURED LEGS **

Variable	Grouping	t Ratio (n)	t Ratio omitting sprains (n-1)
Q60	Group 1	2.70 *	3.55 *
	Group 2	2.07	2.70
	Group 3	1.51	1.56
	Total (n=15)	3.63 *	
	Total (n=12)		4.11 *
Q180	Group 1	2.15	2.47
	Group 2	1.97	2.46
	Group 3	3.14 *	3.95 *
	Total (n=15)	4.52 *	
	Total (n=12)		5.61 *
H60	Group 1	0.68	0.67
	Group 2	2.12	2.84
	Group 3	1.24	1.25
	Total (n=15)	1.92	
	Total (n=12)		1.97
H180	Group 1	1.61	1.70
	Group 2	1.57	1.73
	Group 3	-1.20	-1.21
	Total (n=15)	0.13	
	Total (n=12)		0.12

** Key to abbreviations is found in Appendix A

TABLE 16 (continued)

DEPENDENT SAMPLES t TESTS ON PRETEST SCORES
OF INJURED VS UNINJURED LEGS **

Variable	Grouping	t Ratio (n)	t Ratio omitting sprains (n-1)
QEND	Group 1	-0.11	-0.10
	Group 2	-0.70	-0.68
	Group 3	-0.25	-0.24
	Total (n=15)	-0.54	
	Total (n=12)		-0.54
HEND	Group 1	0.10	0.09
	Group 2	0.73	0.71
	Group 3	-0.19	-0.19
	Total (n=15)	0.56	
	Total (n=12)		0.56

* Statistically significant at the $p<.05$ level

** Key to abbreviations is found in Appendix A

TABLE 17

DEPENDENT SAMPLES t TESTS ON PRETET SCORES OF INJURED VS UNINJURED LEGS OF SUBJECTS WITH/WITHOUT ANTERIOR CRUCIATE LIGAMENT INSUFFICIENCY (ACI) **

Variable	t Value for Subjects With ACI	t Value for Subjects Without ACI
Q60	3.90 *	2.18
Q180	3.91 *	2.87 *
H60	1.02	1.56
H180	-1.04	1.79
QBEND	-1.08	0.59
HBEND	-1.18	1.60

* Statistically significant at the $p<.05$ level

** Key to abbreviations is found in Appendix A

Analyses of variance were used to examine the data reflecting final torque and endurance scores of the injured leg (Appendix D). No significant differences were noted among the three groups (p<.05). The subsequent analyses of covariance, for which posttest scores were used as the dependent variable and pretest scores were used as the covariate, also revealed no significant differences among groups for peak torque and endurance scores (p<.05, Table 18). For all variables except hamstring endurance the pretest scores (the covariate) showed significant effects on the posttest scores.

Dependent samples t tests were used to examine posttest differences between the involved and uninvolved limbs (Table 19). Quadriceps peak torque at 60 deg/sec was significantly greater in the uninvolved legs in Groups 1 and 3; Quadriceps peak torque at 180 deg/sec was significantly greater in the uninvolved leg in Group 1 (p<.05). When data of all subjects in Groups 1 and 2 were combined, uninjured leg scores were significantly greater than injured leg scores for all quadriceps measurements and for hamstring peak torque at 60 deg/sec.

Analyses of variance on difference scores and on difference scores expressed as percentages of the uninjured leg scores revealed no significant differences among groups (p<.05, Appendicies E and F).

Group mean peak torque and endurance values of the uninjured leg are found in Tables 10 and 13. Analyses of variance demonstrated significant differences among groups in the Week 3 measurement of hamstring endurance and in the posttest measurement of quadriceps endurance (p<.05, Appendicies H and I). Duncan Multiple Range tests on Week 3 hamstring endurance showed that the mean of Group 3 was significantly greater than that of Group 1, but that no significant

TABLE 18

ANCOVA TABLES ON POSTTEST SCORES OF THE INJURED LEG COMPARING THREE TREATMENT GROUPS **

Variable	df	Source	Sum of Squares	F
POSQ60B	2	Group	369.79	0.19
	1	Covariate	24660.99	25.86 *
POSQ180B	2	Group	907.99	0.88
	1	Covariate	14226.24	27.47 *
POSH60B	2	Group	538.49	0.53
	1	Covariate	13330.50	26.09 *
POSH180B	2	Group	60.48	0.11
	1	Covariate	6354.21	23.10 *
POSQBEND	2	Group	194.06	2.41
	1	Covariate	809.01	20.07 *
POSHBEND	2	Group	80.81	0.28
	1	Covariate	505.45	3.47

* Statistically significant at the p<.05 level

** Key to abbreviations is found in Appendix A

TABLE 19

DEPENDENT SAMPLES t TESTS ON POSTTEST SCORES COMPARING INJURED VS UNINJURED LEGS **

Variable	Grouping	t Ratio
Q60	Group 1	18.92 *
	Group 2	1.29
	Group 3	2.69 *
	Total (n=15)	4.89 *
	Groups 1 + 2 (n=9)	3.98 *
Q180	Group 1	11.51 *
	Group 2	1.95
	Group 3	1.97
	Total (n=15)	5.03 *
	Groups 1 + 2 (n=9)	5.44 *
H60	Group 1	1.07
	Group 2	0.22
	Group 3	2.05
	Total (n=15)	2.15 *
	Groups 1 + 2 (n=9)	1.02
H180	Group 1	-0.77
	Group 2	0.93
	Group 3	0.49
	Total (n=15)	0.57
	Groups 1 + 2 (n=9)	0.25

* Statistically significant at the $p<.05$ level

** Key to abbreviations is found in Appendix A

TABLE 19 (continued)

DEPENDENT SAMPLES t TESTS ON POSTTEST SCORES COMPARING INJURED VS UNINJURED LEGS **

Variable	Grouping	t Ratio
QGEND	Group 1	3.08 *
	Group 2	2.28
	Group 3	1.74
	Total (n=15)	3.91 *
	Groups 1 + 2 (n=9)	3.80 *
HGEND	Group 1	-1.34
	Group 2	1.11
	Group 3	0.67
	Total (n=15)	0.33
	Groups 1 + 2 (n=9)	0.02

* Statistically significant at the $p<.05$ level

** Key to abbreviations is found in Appendix A

differences occured between means of Groups 2 and 3 or between Groups 1 and 2. Duncan Multiple Range test on posttest quadriceps endurance revealed that the mean of Group 3 was significantly greater than the mean of Group 2 and that no significant differences existed between the means of Groups 1 and 3 or between the means of Groups 1 and 2.

Analyses of variances with repeated measures were used to analyse peak torque and endurance scores of the uninjured leg within each group over the time of the experiment (Appendix J). Significant differences among groups were found only on hamstring torque at 180 deg/sec ($p<.05$). A Newman-Keuls analysis revealed that the Week 3 and posttest means were both greater than the pretest mean but were not significantly different from each other.

Analyses of variance with repeated measures were used to analyse differences among the three test sessions using subjects of Groups 1 and 2, (who did not exercise the uninvolved leg, n=9, Appendix K). Significant differences were noted among subjects in the hamstring peak torque at 60 deg/sec ($p<.05$). The Newman-Keuls analysis demonstrated that posttest scores were significantly greater than pretest and Week 3 scores.

Group mean rates of perceived exertion (RPE) are shown in Table 20. Independent samples t tests revealed no significant differences between the means of groups that attended treatment sessions ($p<.05$).

Mean heart rate data for Group 1 are listed in Table 21. Dependent samples t tests revealed that posttest heart rates were significantly lower that heart rates recorded early in the treatment phase at both 60 and 69 RPM ($p<.05$).

Mean attendance data for Groups 1 and 2 over the six weeks of treatment are listed in Appendix L. A t test for independent samples demonstrated no significant differences between groups ($p<.05$, Appendix D).

The ages of members of each groups are listed in Table 7. The mean ages of members of each group are: Group 1=34.4 years, Group 2= 24.75 years, and Group 3=26.5 years. Analysis of variance for unbalanced data demonstrated no signicant differences among groups ($p<.05$, Appendix M).

TABLE 20

INDEPENDENT SAMPLES t TESTS COMPARING RATES OF PERCEIVED EXERTION OF THE TWO SUPERVISED EXERCISE GROUPS *

		$\bar{x} \pm$ SEM	t Ratio
RPE Week 1	Group 1	4.00 ± 0.47	-0.81
	Group 2	4.59 ± 0.55	
RPE Week 2	Group 1	5.07 ± 0.77	-0.66
	Group 2	5.75 ± 0.75	
RPE Week 3	Group 1	4.93 ± 0.99	-0.30
	Group 2	5.46 ± 1.53	
RPE Week 4	Group 1	4.80 ± 1.01	-0.60
	Group 2	5.67 ± 1.22	
RPE Week 5	Group 1	4.87 ± 0.96	-0.38
	Group 2	5.46 ± 1.28	
RPE Week 6	Group 1	4.73 ± 1.05	-0.52
	Group 2	5.46 ± 0.83	

* Key to abbreviations is found in Appendix A

TABLE 21

DEPENDENT SAMPLES t TESTS ON HEART RATE OF GROUP 1

Heart Rate at 60 Revolutions/Minute

	$\bar{x} \pm$ SEM	t Ratio
Initial	121.2 ± 10.29	-2.69 *
Final	96.00 ± 3.79	

Heart Rate at 69 Revolutions/Minute

Initial	142.80 ± 4.41	-5.66 *
Final	115.20 ± 3.98	

* Statistically significant at the $p<.05$ level

CHAPTER V

Discussion

Difficulty arises when comparing mean peak torque of the subjects in this study with those of previous research. With an infinite number of potential settings for isokinetic contraction, scientists have used a myriad of possible velocities. As angular velocity increases peak torque decreases (Patten Wyatt and Edwards, 1981; Thorstensson, 1976); therefore torques recorded at different angular velocities are not comparable. This study supports earlier findings that as angular velocity increases, maximal peak torque decreases within a range of motion. In addition, variations in sex, age, and level of physical fitness affect results significantly (Larsson et al., 1979; Murray et al., 1980; Goslin and Charteris, 1979). Comparison of peak torque should be made only after data have been corrected for the effects of gravity (Appendix C). Only recently have scientists begun to recognize the importance of this correction in allowing meaningful comparisons of torque among studies (Winter et al., 1981) and to include this correction in the protocols of studies using the Cybex Dynamometer. These factors should be similar in order to derive meaningful comparisons between studies, therefore data of the present study cannot be meaningfully compared to earlier studies.

Statistically significant differences were noted between the injured and uninjured limbs during the pretest for quadriceps peak torque at 60 deg/sec within Group 1 and for quadriceps peak torques at 180 deg/sec within Group 3. When all subjects were considered together (n=15) and when all subjects with meniscal derangements were considered (n=12) significant differences were noted in quadriceps peak torque at both speeds. As the number of subjects was increased, statistically significant differences were seen in more variables. It is possible that with greater numbers in each group significant differences between legs would be noted in each of the groups.

Pretest hamstrings peak torque and endurance differences between legs were completely unlike pretest quadriceps differences. No significant differences were found between legs in any of these measures. It is possible that with greater numbers in each group significant differences would be noted. It seems likely, however, that the hamstrings do not develop the same amount of disuse atrophy after injury that the quadriceps do.

Pretest endurance scores of the injured and uninjured legs were not significantly different. The endurance scores do not reflect the common concept of endurance (low load, high repetitions) but rather the torque generated at the end of thirty maximal contractions relative to that generated at the beginnng of the series. Thorstensson and Karlsson (1976) suggested that in this type of test procedure recruitment of type II fibers occured initially, and that type I fiber recruitment occured as the type II fibers fatigued. Barnes (1980) showed that no significant correlation existed between isokinetic strength and isokinetic endurance at 120 deg/sec. The protocol for determination of endurance scores was found to be very trying for most subjects, therefore the investigator questions whether subjects put maximal effort into all of the contractions. Because of subject difficulties and because reliability of the test has not been established, the validity of this test is questionable.

Postinjury loss of strength is more evident in the quadriceps than in the hamstrings. The quadriceps femoris is a postural muscle group with a fiber composition that averages 50% type I fibers (range 36% to 70%) in young, nonathletic subjects (Thorstensson et al., 1976, Edstrom and Nystrom, 1969, Gollnick et al., 1972). Biochemical and histochemical properties, strength under various conditions and usage are often examined for the quadriceps. In contrast, the hamstrings are seldom studied. In view of their position in the body, the hamstrings are not a postural muscle. Thus the hamstrings would be used less frequently in activities of daily living and might lose less strength with disuse. This perspective may help to explain why the hamstrings suffer much less atrophy after injury or surgery.

In the present study, the dominant leg was defined as the leg with which a subject would kick a ball (as did Patten Wyatt and Edwards, 1981). Of the twelve subjects with meniscal derangements, six had the problem in the dominant and six in the non dominant leg. One would expect that pretest differences between the injured and uninjured legs due to muscle atrophy would be demonstrable if present because of the even split between dominance and non dominance of the injured leg. When considering the data of subjects with meniscal derangements, the pretest differences in torque between the injured and uninjured legs represented 83% and 85% of the uninjured quadriceps scores, 92% and 99.4% of uninjured hamstring scores of the at low and high speeds respectively. The first three percentages were greater than the findings of Patten Wyatt and Edwards (1981). (Only the quadriceps differences were statistically significant however.) The controversy over the strength of the dominant and non dominant legs in relation to each other prohibits the formation of strict conclusions about the loss of strength after injury. The even distribution of injury to the dominant and non dominant legs among subjects with meniscal derangements, however, allows the suggestion that a trend towards postinjury atrophy was demonstrated.

Investigations of muscle atrophy in humans have typically assessed biochemical and contractile properities of muscle after immobilization rather than after injury. Decreased girth, leg volume, peak torque, strength, oxidative capacity and some intramuscular fuels have been noted (MacDougall et al., 1977; 1980; Sargeant and Davies, 1977; Davies and Sargeant, 1975; Hulten et al., 1981; Grimby et al., 1980; Eriksson, 1976; Costill et al., 1977. Greater atrophy in type I than type II fibers of vastus lateralis has been reported both after immobilization and with knee joint instability (Sargeant and Davies, 1977; Edstrom, 1970). Edstrom (1970) is one of few scientists who has examined the vastus lateralis muscle after injury rather than after immobilization subsequent to injury. While all of these parameters were not investigated in the present study, findings of decreased quadriceps peak torques were not at odds with these studies.

Neurological factors have also been noted to contribute to muscle atrophy. These include: joint capsule edema, sectioning of the joint capsule, and pain (Gardner, 1948; deAndrade et al., 1965; Gydikov, 1976; and Eriksson, 1981). Joint capsule edema and pain were both evident in subjects of this study. It should be noted that subjects experienced anterior knee and quadriceps pain but no hamstring pain.

Detraining studies may add some support to the assumption that decreasing the level of activity of a muscle will lead to decreases in strength and various biochemical parameters within the muscle. Such studies, however, follow or include a period of physical training, which commonly creates augmented performance and increased biochemical parameters. While such factors prohibit strict application of findings to subjects who, after joint injury, were forced to use the affected limb less in activities of daily living, parallels may exist between the two models.

In a detraining study conducted by Henriksson and Reitman (1977), subjects participated in eight to ten weeks of endurance training followed by six weeks of detraining. The authors noted decreased oxidative capacity in vastus lateralis as indicated by return of SDH and CO activities to pretraining levels. Houston et al. (1979) noted that fifteen days of detraining in well trained endurance runners caused significant decreases in SDH and LDH activities, a 25% decrease in performance, and a 4% decrease in MaxVO2. Green et al., (1980) examined the effects of detraining on varsity hockey players. They noted decreases in ATP, CP, and glycogen content of vastus lateralis, and decreases in SDH, HADH, phosphorylase and PFK, while noting no change in fiber size or type. Sysler and Stull (1970) noted significant decreases in muscular endurance after three and five weeks of detraining following seven weeks of endurance isotonic training. No significant difference was noted between three and five weeks of detraining.

Subjects with meniscal derangements in this study reported intermittent or continuous knee joint dysfunction, pain, swelling and subsequent decreased use for up to five years prior to surgery (Table 7). This time classification is not exact, however, because it is dependent on the subjects' response to questioning during the first appointment with the investigator. Great variation in the level of dysfunction was also found among subjects. One subject had been on crutches for three months prior to surgery, while some subjects were able to participate in all of their usual activities. These factors prevent firm categorization as to the length and level of dysfunction and disability and illustrate a major problem that exists in the investigation of clinical disuse atrophy subsequent to injury without immobilization. Results of this study suggest a trend toward decreased strength in the quadriceps femoris muscle group. Without biochemical, and histochemical analysis or examination of physiological parameters such as VO2 Max, no comparisons can be drawn between the present study and studies that have documented these physiological changes.

Edstrom (1970) demonstrated evidence of muscular atrophy among subjects with six month to four year histories of anterior cruciate ligament insufficiency. Clinically, the muscle of the untreated, unbraced anterior cruciate insufficient knee is frequently noted to be weaker than the uninvolved leg (personal communication with Dr. P Fowler). Results of a dependent samples t test revealed significant differences between the quadriceps peak torque at 60 and 180 deg/sec (n=6 Table 17). These subjects had 1.25 to 4.25 year histories of anterior cruciate ligament insufficiency (Table 7). This evidence supports Edstrom's findings of quadriceps atrophy in the chronic anterior cruciate insufficient knee. Again, no significant differences between hamstrings peak torque, quadriceps or hamstrings endurance between legs were noted. Anterior cruciate ligament injuries have also been noted to be associated with a high incidence of meniscal tears (personal communication with Dr. P. Fowler, Noyes et al., 1980). Noyes et al. (1980) noted that in a survey of 103 patients with knee derangement, 62% of these patients with incomplete and complete anterior cruciate insufficiency also had meniscal tears. Because of the frequency of this combination of injuries, it was important to include such subjects in the present study. Despite an attempt to distribute subjects with chronic anterior cruciate ligament insufficiency evenly among the groups, the final distribution of these subjects was as follows: Group 1- one female subject, Group 2- one female subject, one male subject, Group 3- one female subject, two male subjects. It is not known whether this uneven distribution affected the results.

The ANOVAs on posttest scores of the involved limb revealed no significant differences among groups. The ANCOVAs done on the same posttest scores, using the pretest scores of the injured limb as the covariate, also revealed no significant differences among the groups. The covariate, (the initial torque or endurance score) had a significant effect on the posttest scores as evidenced by the significant F values for all covariates except hamstring endurance. Mueller (1968) stated that individuals have strength limits and that the training time from the initial strength to the strength limit is not necessarily equal for all subjects. It seems important, therefore to consider the subjects' initial levels of strength using analyses of covariance. No program was shown to augment strength or endurance more successfully than any other program. Differences may be seen if greater numbers of subjects are included in the study of if training is continued for longer.

It should be noted that those trained without supervision and thus without as much 'formal' exercise did as well or better than those who attended 18 supervised exercise sessions. Five of the six subjects in Group 3 indicated in their diaries that they participated in walking, running, bicycling or stationary bicycling as well as exercising three or more times a week for at least three of the six weeks of treatment. While these effects should be investigated further, home exercise and activity should be strongly considered for individuals after arthroscopic surgery, and possibly included to augment formalized therapy. Further investigation might reveal whether structured rehabilitation is necessary at all for such patients. Within the present Ontario medical system, the possibility of moving towards fewer treatments, more assessment and consultation regarding exercise and activity should be considered. Such moves could represent a helpful saving of public medical care dollars, and would create openings for other patients who now remain on waiting lists for therapy.

Posttest differences between the involved and uninvolved limbs demonstrated that all quadriceps scores and hamstring peak torque at the 60 deg/sec of the involved leg were significantly lower than those of the uninvolved leg (Tables 14, 15, 19). Differences between legs were greater than those noted between dominant and non dominant by Patten Wyatt and Edwards (1981). It is thus important to consider the fact that six weeks of various types of rehabilitative exercise used in this study were not sufficient to return the injured limb to the level of the uninjured limb. Even when trying to make concessions for the differences between dominant and non dominant legs, the injured leg had not returned to the level of the uninjured leg. Most research conducted to date that has investigated rehabilitation programs for various conditions considered rehabilitation to the level of the uninvolved leg regardless of dominance (Campbell and Glenn, 1979; 1982; Grimby et al. 1980; Sargeant et al., 1977). It should be noted that at the end of six weeks of treatment all subjects were pain free, had no knee joint effusion, and felt no residual disability in the knee. From this point of view, without the objective assessment of strength, most of the subjects felt that six weeks of rehabilitation was too long a time to continue formalized treatment. Objective evaluation of peak torque, however, supports the opposite conclusion. It is important to investigate longer rehabilitation programs to determine if and when strength is ever fully restored.

Length of treatment and discharge criteria are important considerations in rehabilitation programs. Campbell and Glenn (1979) found that subjects who had undergone menisectomies (through arthrotomies) and who had also undergone a three stage rehabilitation program still demonstrated significant differences in peak torque between legs in isometric knee flexion, flexion at 210 deg/sec and in knee extension at 210 deg/sec. Similarly, Campbell and Glenn (1982) found that peak torque for knee extension at 30 and 180 deg/sec in patients who had undergone menisectomies or ligament repair had not returned to the level of the uninvolved leg ($\bar{x}$ time for menisectomies = [illegible]0 days, $\bar{x}$ time for ligament repairs = 120 days). The present study indicated that a six week rehabilitation program post arthroscopy was not sufficient to strengthen a limb back to level of the uninjured limb.

ANOVAs on posttest differences between the involved and uninvolved limb scores and on the difference scores expressed as percentages of the uninvolved limb revealed no significant differences among groups (Appendicies E and F). While t tests revealed significant differences between the limbs, no one program brought the involved limb to the level of the uninvolved more adequately. With greater numbers of subjects, differences may be seen. It was interesting to note that in this study, the home exercise program seemed at least as effective as the supervised programs, and thus, the home program could be considered more efficient from some perspectives. The uneven distribution of numbers of subjects in the groups (Group 1 n=5, Group 2 n=4, Group 3 n=6) and the possibility that subjects in Group 3 were more active than those in Groups 1 and 2 may have affected results.

The ANOVAs on scores of the uninjured legs revealed no significant differences among groups at any of the three testing sessions (Appendicies G, H and I). When each group was analysed individually over time using ANOVAs with repeated measures, significant differences were noted only among testing times for Group 3 for hamstring torque at 180 deg/sec. Post hoc analysis revealed only that both Week 3 scores and posttest scores were greater than the pretest score. These results may suggest an actual increase in muscle strength in the first three weeks of treatment in this isolated instance. These results may, instead, reflect the subjects increased familiarity with the test procedure. Each of these explanations is undermined by the lack of change of any other set of scores over time. When all subjects in the two supervised exercise groups (who did not exercise the uninvovled leg) were analysed together, significant results were noted only in peak hamstring torque at 60 deg/sec (Appendix K). Post hoc analysis revealed that the posttest mean was significantly greater than the pretest mean. Again it is possible for strength to have increased over the time of the study; increased familiarity with the procedure may also be a factor in the higher posttest scores. Mawdsley and Knapik (1982) found that no strength increases occured as a result of isokinetic testing two weeks apart. Johnson and Siegel (1978) found that familiarity over three test days did not affect peak torque that, with the exception of hamstring torque, no changes in peak torque or endurance occured in the uninvolved leg over the seven to eight week period from pretest to posttest. A major limitation of this examination remains the small number of subjects included in the study.

Independent samples t tests revealed no significant differences between weekly average rates of perceived exertion (RPE) for Groups 1 and 2 (table 20). It was interesting to note that during cycling, heart rates consistently achieved (and were held to) 75% to 80 % of the predicted maximum heart rate, that respiratory rates were elevated and that subjects perspired noticeably. Subjects in Group 2 showed heart rate increases of no more than 30 beats/minute above resting levels, respiratory rates were not elevated as noteably, and increases in perspiration were much less marked. The contrast in these physiological parameters was marked, yet no differences in RPE were noted. While it would have been desireable to examine the correlation between strength gain and RPE in those subjects who achieved the greatest and least strength gains. The small number of subjects attending supervised exercise sessions made such regrouping for analysis difficult.

The initial and final heart rate responses to the interval cycling program were examined in subjects of Group 1. Exercise heart rate during cycling both at 60 RPM and at 69 RPM decreased significantly with treatment. Cardiovascular and biochemical benefits of continuous cycling in leg rehabilitation have been demonstrated (Costill et al., 1977; Davies and Sargeant, 1975) in the forms of increased VO2 Max, increased SDH activity, and increased absolute work capacity. Such benefits of interval programs have not been assessed within rehabilitation programs. McKenzie et al., (1978) demonstrated that leg or arm interval cycling programs of thirty second repetitions resulted in increases in VO2 Max, decreased submaximal heart rate, and decreased venous lactic acid. While such physiological parameters were not investigated in the present study there was evidence of central aerobic benefits caused by the interval program. The interval training based exercise program was designed to augment performance of the ATP-CP and contractile systems in muscle in accordance with principles outlined by Fox and Mathews (1974). It is impossible to evaluate the effects of the program on the ATP-CP system, however, without the use of muscle biopsies, biochemical analysis of enzymatic activities and amounts of stored substrates available in the muscle. The application of interval training to rehabilitation merits further investigation.

One important area of potential error in this study was use of the Cybex II Isokinetic Dynamometer. While the investigator attempted to follow the protocol for dynamometer calibration recommended by Lumex

Inc., lack of expertise with this machine may have affected results. The machine was calibrated twice weekly. The possibility of error existed because often several subjects were tested between calibrations. Intermittent problems were experienced with the dual channel recorder. A jumpy movement of the recording paper at the 25 mm/sec speed, a loosening of the damping control button and the electrogoniometer caused problems which were remedied as best as possible within the limits of the staff of the University of Western Ontario Athletic Injuries Clinic and the investigator. These intermittent difficulties could have also introduced error into the recordings.

The gravitational correction was also a possible source of error. The protocol followed in the present study (Appendix C), was that suggested by Lumex Inc.. Accuracy depended on the subject's complete relaxation when dropping the leg and lever arm from above the horizontal. Several trials were conducted in an attempt to gain this relaxation. This subjective judgement of the investigator could have been inaccurate, thus leading to an erroneous estimate of the effects of gravity on the limb and lever arm, and eventual inaccurate estimation of peak torque. The intermittent malfunctioning of the damping control and electrogoniometer could have also contributed to error in determination of the actual peak torque scores of the joint angle at which peak torque occcured.

The nature of the torque overshoot has been examined with the use of cinematographic analysis (Sapega et al., 1982). The authors concluded that initial high spikes in Cybex torque recordings represented an inertial artifact rather than contractile characteristics of the muscle. Overshoot represented the torque required to decelerate the limb and arm of the dynamometer during reciprocal movement. The investigator in the present study thus attempted to record the level of torque noted after any initial overshoots. Error could have arisen due to inaccurate assessment of the overshoot spikes, however.

While damping on the Cybex recorder represents electronic suppression of overshoot spikes, Sapega et al. (1982) pointed out that damping beyond the setting of 2 (on the adjustable scale of 0 to 4) suppressed grossly appreciable quantities of true muscular torque as well as the overshoot, thus simply substituting one artifact for another. The authors stated that as the velocity of contraction increased, the overshoot was spread over relatively greater amounts of the torque curve, thus causing "the frequency of the artifact waveform and muscular torque curve to approach each other reducing the ability of the damping circuit to supress the overshoot selectively" (p. 375). In addition, these authors suggested that the problems may not be consistent among subjects. On two specific occasions the investigator questioned whether the damping control was actually operating correctly.

CHAPTER VI

Summary and Conclusions

The present study was designed to compare the effects of three rehabilitative exercise programs designed for patients who have experienced knee injury and arthroscopic surgery. The programs were: 1. supervised interval training based bicycle ergometry and progressive resisted concentric hamstring exercise (Group 1); 2. supervised untimed progressive resisted concentric quadriceps and hamstring exercise (Group 2); and 3. unsupervised home exercise and activity (Group 3).

It was hypothesized that there would be no significant difference between pretest scores of the injured and uninjured legs. It was also hypothesized that quadriceps or hamstring peak torque and endurance scores of the injured leg would not differ significantly among groups. It was further hypothesized that there would be no significant differences in posttest difference scores among groups. It was hypothesized that there would be no significant differences among groups for scores of the uninjured leg. Furthermore, it was suggested that there would be no significant differences within each group for scores of the uninjured leg over the time of the experiment. Finally, it was hypothesized that there would be no significant differences between rates of perceived exertion of the two supervised treatment groups.

Fifteen subjects, including twelve males and three females (mean age= 28.67, SEM 2.94 years) were matched and assigned to one of the three exercise groups (Group 1 n=5, Group 2 n=4, Group 3 n=6). Twelve subjects underwent arthroscopic investigation for possible meniscal derangement. Two subjects had suffered medial collateral ligament sprains and one subject had sustained a lateral collateral and anterior cruciate ligament sprain. No significant differences in age were noted among the groups. Members of Groups 1 and 2 performed supervised exercise three times weekly for six weeks. No significant differences in attendance were noted between groups. Group 3 attended testing sessions and received a program of home exercises to perform for the duration of the experiment. In addition, these subjects were instructed to participate in any physical activity that they wished within the limits of their injured knees.

Testing sessions were carried out on subjects with suspected meniscal lesions: preoperatively, on both legs; four to seven days postoperatively, on the injured leg; after three weeks of exercise, on the uninjured leg; and after the six week exercise program, on both legs. Subjects who had sustained ligament sprains were tested post injury after three and six weeks of exercise. The immediate postoperatve test results were discarded. Tests were performed on a Cybex II isokinetic dynamometer and test parameters were: quadriceps and hamstring peak torque at 60 and 180 deg/sec, and quadriceps and hamstring endurance. At the end of each treatment, subjects in Groups 1 and 2 were asked to give a rating of perceived exertion for the session. Exercise heart rates were monitored in subjects who performed the interval training based exercise.

Dependent samples t tests revealed significant differences between pretest injured and uninjured legs in quadriceps peak torque at 60 and 180 deg/sec ($n=15$, $p<.05$). Significant differences between legs were noted only in Group 1 for quadriceps peak torque at 60 deg/sec and in Group 3 for quadriceps peak torque at 180 deg/sec ($p<.05$).

One way ANOVAs for unbalanced data revealed no significant differences among groups for any posttest measure of the injured leg ($p<.05$). Subsequent ANCOVAs for unbalanced data (using posttest scores as the covariate) revealed no significant differences among groups ($p<.05$).

One way ANOVAs for unbalanced data revealed no significant differences among groups on differences scores derived from subtracting the posttest scores of the injured leg from the posttest scores of the uninjured leg ($p<.05$). Similar nonsignificant results were obtained when difference scores expressed as percentages of the uninjured leg were analysed ($p<.05$).

Dependent samples t tests were used to examine differences between posttest scores of the injured and uninjured leg. When data of Groups 1 and 2 were analysed together, significant differences were noted in peak quadriceps torque at both speeds, in peak hamstring torque at 60 deg/sec and in quadriceps endurance. Analyses by group revealed significant differences in quadriceps peak torque at 60 deg/sec for Groups 1 and 3, and in quadriceps peak torque at 180 deg/sec for Group 1 ($p<.05$).

Data of the uninjured leg were analysed using ANOVAs for unbalance data. Significant differences were noted among groups for

Week 3 hamstring endurance and for posttest quadriceps endurance ($p<.05$). Post hoc analysis on hamstring endurance revealed only that Group 3 was greater than Group 1. Post hoc analysis on quadriceps endurance revealed only that Group 3 was greater than Group 2.

ANOVAs with repeated measures were used to assess changes in scores of the uninjured leg over time within each group. Significant differences were found only within Group 3 for peak hamstring torque at 180 deg/sec. Post hoc analysis demonstrated that both Week 3 and posttest scores were greater than pretest scores ($p<.05$). When data of Groups 1 and 2 were analysed together, significant differences were seen in peak hamstring torque at 60 deg/sec. Post hoc analysis showed only that posttest scores were greater than pretest scores ($p<.05$).

Independent samples t tests revealed no significant differences between rates of perceived exertion of Groups 1 and 2 for any week during treatment ($p<.05$). Dependent samples t tests showed significant decreases in exercise heart rates of subjects in Group 1 after six weeks of treatment ($p<.05$).

Disuse atrophy (manifested by decreases in peak torque in the injured limb when compared to the uninjured limb) was demonstrated in subjects with two month to five year histories of knee joint problems. This atrophy was more noteable in the quadriceps than in the hamstrings. Further study of this phenomenon is necessary to understand the biochemical, histochemical and contractile changes that occur after injury in each muscle group.

The results of the present study suggest that none of these six week programs of rehabilitative exercise was of sufficient length or complexity to return the injured leg to the level of the uninjured leg in quadriceps peak torque at 60 or 180 deg/sec, quadriceps endurance or hamstring peak torque at 60 degree/second. Consideration should be given to developing more extensive programs of exercise and to continuing the rehabilitation process for longer periods of time. In addition, no one exercise program was significantly better at returning the injured limb to the level of the uninjured limb. Increased levels of daily activity may play an important part in rehabilitation of this muscle group. This component of rehabilittion should be investigated further.

The findings of the present study suggest that little change in peak torque and endurance occur in the uninjured limb over the rehabilitation process.

Heart rate data from Group 1 strongly suggest that the interval training based exercise program contributes to improved cardiovascular status in the subjects. Further development of this program and more extensive investigation of physiological parameters are needed to fully explore the potential of such interval training based exercise in rehabilitation.

Analyses of rates of perceived exertion (RPE) suggested that despite vast differences in cardiorespiratory parameters during exercise, no differences in RPE were noted. Further exploration of differences among these types of programs may lead to some insights into patients' perception of rehabilitation programs.

Recommendations for Further Study:

The results of the present study suggest several possibilities for further study.

Study of biochemical parameters within muscle before, during, and after treatment could provide some valuable insights. Through such investigation, the effects of disuse and exercise on muscle fiber types and areas, and on the metabolic pathways and substrates could be determined. Examination of muscle during exercise could help to determine the actual metabolic pathways used for interval training based exercise. The detailed study of physiological parameters such as oxygen uptake, heart rate, and blood pressure during interval work would demonstrate what effects the exercise program has on the aerobic system.

The interval training based exercise program seems to hold some promise for use in rehabilitation. Investigation of the above mentioned parameters would help to evaluate whether interval training is, in fact, a useful type of exercise for rehabilitation. The interval program itself should be redesigned to provide the most difficult workout that can be tolerated by patients. In order to evaluate the effects of either cycling or timed weight training these exercises should be applied and tested as separate protocols.

Several areas of study of the hamstring muscle group would be beneficial to increase understanding of the role of the hamstrings during activity, and after injury and immobilization. Investigation of the biochemical and histochemical properties and electromyographic activity would help to clarify the role of this muscle.

Endurance testing on the isokinetic dynomometer should be reviewed and its reliability determined. If shown to be reliable, an assessment of the amount of work done during the test may offer a more meaningful measure of endurance for rehabilitative purposes.

Further investigation of the length of time necessary for return of the injured leg to the level of the uninjured leg should be carried out. Consideration should also be given to determining what rehabilitation goals (in terms of peak muscle torque) should be established to minimize chances of reinjury.

Home exercise programs should also be further investigated Exercise groups with greater numbers of controls than those used in the present study would help to determine whether effective rehabilitation can be carried out with minimal supervision.

Finally, it seems important to study the effects of these rehabilitation programs using greater numbers of subjects and with more evenly matched groups.

References

Alexander, J., and Molnar, G. E. "Muscular strength in children preliminary report on objective standards." Arch. Phys. Med. Rehab. 54:424-4277, 1973.

Astrand, P.-O., and Rodahl, K. "Textbook of Work Physiology." New York: McGraw-Hill Book Co., 1977.

Barnes, W.S. "The relationship between maximum isokinetic strength and isokinetic endurance." Res. Q. Exer. Sport 51:714-717, 1980.

Basset, F. and Whipple, T. "Arthroscopic examination of the knee." J. Bone and Joint Surg.(Am) 60:444-453, 1978.

Berger, R.A. " Effect of varied weight training programs on strength." Res. Q. 33:168-181, 1962a.

Berger, R.A. "Optimum repetitions for the development of strength." Res. Q. 33: 334-338, 1962b.

Berger, R.A. "Comparison between static training and various dynamic training programs." Res. Q. 34:131-135, 1963.

Berger,R.A. "Comparison of the effect of various weight training loads on strength.", Res. Q. 36:141-152, 1965.

Booth, F.W. "Time course of muscular atrophy during immobilization of hindlimbs in rats." J. Appl. Physiol. 43:656-661, 1977.

Booth, F. W., and Kelso, J. R. "Production of rat muscle atrophy by cast fixation. J. Appl. Physiol." 34:404-406, 1973.

Borg, G. A. V. "Perceived exertion: a note on "history" and "methods." Med. Sci. Sports. 5:90-93, 1973.

Borg, G. A. V., and Noble, B. J. Perceived exertion. In: "Exercise and Sport Sciences Reviews." J. H. Wilmore (Ed.), New York: Academic Press, 2:131-153, 1974.

Borg, G. A. V. "Psychophysical bases of perceived exertion." Med. Sci. Sports and Ex. 14:377-381, 1982.

Campbell, D. E., and Glenn, W. "Foot-pounds of torque of the normal and the rehabilitated post menisectomy knee." Phys. Ther. 59: 418-421, 1979.

Campbell, D. E. and Glenn, W. "Rehabilitation of knee flexor and knee extensor muscle strength in patients with menisectomies, ligamentous repairs and chondromalacia." Phys. Ther. 62:10-15, 1982.

Cassell, S. E. "A survey of rehabilitation techniques following traumatic injuries to the knee of the male in selected colleges and universities." Unpublished M.Sc. Thesis, Western Illinois University. 1973.

Clarke, D. H. Adaptations in strength and muscular endurance resulting from exercise. In: "Exercise and Sport Science Reviews." J. H. Wilmore (Ed.), New York: Academic Press, 1:73-102, 1973.

Clarke, H. H., Shay, C. P. and Mathews, D. K. "Strength and endurance (conditioning) effects of exhaustive exercise of the elbow flexor muscles." J. Assoc. Phys. Ment. Rehab. 8:184-188, 1954.

Costill, D. H., Fink, W. J., Habansky, A. J. "Muscle rehabilitation after knee surgery." Physician and Sportsmedicine. 5:71-74, 1977.

Coyle, E. F., Feiring, D. C., Rotkis, T. C., Cote III, R. W., Roby, F. B., Lee, W., and Wilmore, J. H. "Specificity of power improvements through slow and fast isokinetic training." J. Appl. Physiol.: Respirat. Environ. Exercise Physiol. 51:1437-1442, 1981.

Darcus, H. D., and Salter, N. "The effects of repeated muscular exertion on muscle strength." J. Physiol. (Lond.). 129:325-326, 1955.

Davies, C. T. M., and Sargeant, A. J. "Changes in physiological performance of the lower limb after fracture and subsequent rehabilitation." Clin. Sci. Mol. Med. 48:107-114, 1975.

deAndrade, J. R., Grant, C., and Dixon, A. St. J. "Joint distension and reflex inhibition in the knee." J. Bone. Joint. Surg. 47A: 313-322, 1965.

DeLorme, T. L. "Restoration of muscle power by heavy resistance exercises." J. Bone and Joint Surg. (Am.) 27:645-667, 1945.

DeLorme, T. L., and Watkins, A. L. "Techniques of progressive resistance exercise." Arch. Phys. Med. 29:263-273, 1948.

Eddy, D. O., Sparks, K. L., and Adelizi, D. A. "The effects of continuous and interval training in women and men." Eur. J. Appl. Physiol. 37:83-92, 1977.

Edstrom, L. "Selective atrophy of red muscle fibers in the quadriceps in long-standing knee joint dysfunction injuries to the anterior cruciate ligament. J. Neurol. Sci. 11:551-558, 1970.

Eriksson, E. "Sports injuries of the knee ligaments: their diagnosis, treatment, rehabilitation, and prevention." Med. Sci. Sports. 8: 133-144, 1976.

Eriksson, E. "Rehabilitation of muscle function after sport injury-major problems in sports medicine." Int. J. Sports Med. 2:1-6, 1981.

Fox, E. L. "Measurement of the maximal alactic (phosphagen) capacity in man." Med. Sci. Sports. 5:66, 1973.

Fox, E. L., and Mathews, D. K. "Interval Training Conditioning for Sports and General Fitness." Philadelphia: W. B. Saunders Co. Co., 1974.

Fox, E. L. and Mathews, D. K. "The Physiological Basis of Physical Education and Athletics." Philadelphia: Saunders College Publishing, 1981.

Fox, E. L., Bartels, R. L., Klinzing, J., and Ragg, K. "Metabolic responses to interval training programs of high and low power output." Med. Sci. Sports. 9:191-196, 1977.

Gardiner, G. W. "Specifity of strength changes of the exercised and non exercised limb following isometric training." Res. Q. 34:98-101, 1963.

Gardner, E. D. "The innervation of the knee joint."Anat. Rec. 100: 109-130, 1948.

Gilliam, G. M. "Effects of frequency of weight training on muscle strength enhancement." J. Sports Med. Phys. Fit. 21:432-436, 1982.

Goslin, B. R. and Charteris, J. "Isokinetic dynamometry for clinical use in lower extremity (knee) cases." Scand. J. Rehab. Med. 11: 105-109, 1979.

Green, H. J., Thomson, J. A., Daub, B. D., and Ranney, D. A. "Biochemical and histochemical alterations in skeletal muscle in man during a period of reduced activity." Can. J. Physiol. Pharmacol. 58:1311-1316, 1980.

Grimby, G., Gustafsson, E., Peterson, L., and Renstrom, P. "Quadriceps function and training after leg surgery." Med. Sci. Sports. 12:70-75, 1980.

Guhl, J. F. "Operative arthroscopy." Am. J. Sports Med. 7:328-335, 1979.

Gydikov, A. Patterns of discharge of different types of alpha motor units during voluntary and reflex activities under normal physiological conditions. In: "Biomechanics VA." P. Komi (Ed.), Baltimore: University Park Press, 1976.

Hollering, B. L., Fox, E. L., Bartels, R. L., and Mathews, D. K. "Metabolic energy sources as affected by a seven week program of interval training." Physiologist. 14:165, 1971.

Hellebrandt, F. A. "Cross education: ipsilateral and contralateral effects of unimanual training." J. Appl. Physiol. 4:136-144, 1951.

Henriksson, J. and Reitman, J. S. "Time course of changes in human skeletal muscle succinate dehydrogenase and cytochrome oxidase activities and maximal oxygen uptake with physical activity and inactivity." Acta Physiol. Scand. 99:91-97,1977.

Houston, M. E. Bemtzen, H. and Larsen, H. "Interrelationships between skeletal muscle adaptations and performance as studied by detraining and retraining." Acta Physiol. Scand. 105:163-170,1979.

Hulten, B., Renstrom, P., and Grimby, G. "Glycogen-depletion patterns with isometric and isokinetic exercise in patients after leg injury." Clin, Sci. Mol. Med. 61:35-42, 1981.

Hultman, E., Bergstrom, J., and McLennan Anderson, N. "Breakdown and Resynthesis of phosphorylcreatine and adenosine triphosphate in connection with muscular work in man." Scand. J. Clin. Lab. Invest. 19:56-66,1967.

Jayson, M. I. V., and Dixon, A. St. J. "Intra-articular pressure in rheumatoid arthritis of the knee." Ann. Rheum. Dis. 29: 408-410, 1970.

Johnson B. L., Adamczyk, J. W., Tennoe, K. O., and Stromme, S. B. "A comparison of concentric and eccentric muscle training." Med. Sports Sci. 8:35-38, 1976.

Johnson, J. and Siegel, D. "Reliability of an isokinetic movement of the knee extensors." Res. Quart. 49:88-90, 1978.

Karlsson, J., Funderburk, C. F., Essen, B., and Lind, A. R. "Constituents of human muscle in isometric fatigue." J. Appl. Physiol. 38:208-211, 1975.

Knight, K. L., Martin, J. A., and Londree, B. R. "EMG comparison of quadriceps femoris activity during knee extension and straight leg raises." Am. J. Phys. Med. 58:57-69, 1979.

Komi, P. V., and Buskirk, E. R. "Effect of eccentric and concentric muscle conditioning on tension and electrical activity of human muscle." Ergonomics. 15:417-434, 1972.

Lamb, D. R. "Physiology of Exercise Responses and Adaptations." New York: Macmillan Co., 1978.

Larsson, L., Grimby, G., and Karlsson, J. "Muscle strength and speed of movement in relation to age and muscle morphology." J. Appl. Physiol.: Respirat. Environ. Exercise Physiol. 45: 451-455, 1979.

Liberson, W. T., and Asa, M. M. "Further studies of brief isometric exercises." Arch. Phys. Med. Rehab. 40:330-336, 1959.

Lindh, M. "Increases of muscle strength from isometric quadriceps exercises at different knee angles." Scand. J. Rehab. Med. 11: 33-36, 1979.

MacDougall, J. D., Ward, G. R., Sale, D. G., and Sutton, J. R. "Biochemical adaptations of human skeletal muscle to heavy resistance training and immobilization." J. Appl. Physiol.: Respirat. Environ. Exercise Physiol. 43:700-703, 1977.

MacDougall, J. D., Elder G. C. B., Sale, D. G., Moroz, J. R., and Sutton, J. R. "Effects of strength training and immobilization on human muscle fibers." Eur. J. Appl. Physiol. 43:25-34, 1980.

McKenzie, D. C., Fox, E. L., and Cohen, K. "Specificity of metabolic and circulatory responses to arm or leg interval training." Eur. J. Appl. Physiol. 39:241-248, 1978.

Malone, T., Blackburn, T. A., and Wallace, L. A. "Knee rehabilitation" Phys. Ther. 60:1602-1610, 1980.

Margaria, R., Ceretelli, P., and Mangili, F. "Balance and kinetics of anaerobic energy release during strenuous exercise in man." J. Appl. Physiol. 19:623-628, 1964.

Margaria, R. "Anaerobic metabolism in muscle." Can. Med. J. 96:770-774, 1967.

Margaria, R., Oliva, R. D., Diframpero, P. E., and Cerretelli, P. "Energy utilization in intermittent exercise of supramaximal intensity." J. Appl. Physiol. 26:752-756, 1969.

Mathews, D. L., and Fox, E. L. "The Physiological Basis of Physical Education and Athletics." Philadelphia: W. B. Saunders Co., 1976.

Mawdsley, R. H., and Knapik, J. J. "Comparison of isokinetic measurements with test repetitions." Phys. Ther. 62:169-172, 1982.

Meyers, C. R. "Effects of two isometric routines on strength, size, and endurance in the nonexercised arms." Res. Q. 38:430-440, 1967.

Moffroid, M., Whipple, R., Hofkosh, J., Lowman, E., and Thistle, H. "A study of isokinetic exercise." Phys. Ther. 49:735-747, 1969.

Muller, E. A. "The regulation of muscular strength." J. Assoc. Ment. Rehab. 11:41-47, 1957.

Muller, E. A. "Physiology of muscle training." Rev. Can. Biol. 21: 303-313, 1962.

Muller, E. A. Physiology of muscle training. In: "Classical Studies on Physical Activity" R. C. Brown (Ed.),Englewood Cliffs, New Jersey: Prentice-Hall Inc., 1968.

Murray, M. P., Gardner, G. M., and Mollinger, L. A. "Strength of isometric and isokinetic contractions in knee muscles of men aged 20 to 86." Phys. Ther. 60:412-419, 1980.

Noyes, F. R.,Paulos, L., Mooar, L. A., and Signer, B. "knee sprains and acute knee hemarthrosis." Phys. Ther. 60:1596-1601, 1980.

O'Donoghue, D. H. "Treatment of Injuries to Athletes." Philadelphia: W. B. Saunders Co., 1976.

O'Donoghue, D. H. "Menisectomy indications and management." Phys. Ther. 60:1617-1623, 1980.

O'Shea, D. "Effects of selected weight training programs on the development of strength and muscle hypertrophy." Res. Q. 37:95-102, 1966.

Patel, A. N., Razzak, Z. A., and Dastur, D. K. "Disuse atrophy in human skeletal muscles." Arch. Neurol. 20:413-421, 1969.

Patten Wyatt, M. and Edwards, A. M. "Comparison of quardriceps and hamstring torque values during isokinetic exercise." J. Orthopaedic Sports Physical Therapy 3:48-56, 1981.

Pettrone, F. A. "Menisectomy" arthrotomy versus arthroscopy." Am J. Sp. Med. 10:355-359, 1982.

Pipes, T. V., amd Wilmore, J. H. "Isokinetic vs isotonic strength training on adult men." Med. Sci. Sports. 7:262-274, 1975.

Rasch, P. J., and Morehouse, L. E. "Effect of static and dynamic exercises on muscular strength and hypertrophy." J. Appl. Physiol. 11:29-34, 195

Ready, A. E. "The effect of interval training and detraining on anaerobic fitness in women." Unpublished M. A. Thesis, University of Western Ontario, 1977.

Saltin, B., and Rowell, L. B. "Functional adaptations to physical activity and inactivity." Fed. Proc. 39:1506-1513, 1980.

Sapega, A. A., Nicholas, J. A., Sokolow, D., and Saranti, A. "The nature of torque "overshoot" in Cybex isokinetic dynamometry Med. Sci. Sports Exercise 14:368-375,1982.

Sargeant, A. J., and Davies, C. T. M. "The effect of disuse muscular atrophy on the forces generated in dynamic exercise." Clin. Sci. Mol. Med. 53:183-188, 1977.

Sargeant, A. J., Davies, C. T. M., Edwards, R. H. T., Mauder, C., and Young, A. "Functional and structural changes after disuse of human muscle." Clin. Sci. Mol. Med. 52:337-342, 1977.

Seliger, V., Dolejs, L., and Karas, V. "A dynamometric comparison of maximum eccentric, concentric and isometric contractions using EMG and energy expenditure measurements." Eur. J. Appl. Physiol. 45:235-244, 1980.

Stafford, P. "Electromyography of the quadriceps femoris muscles with normal knees and acutely effused knees." Phys. Ther. 62:279-283, 1982.

Sysler, B. L. and Stull, G. A. "Muscular endurance retention as a function of length of detraining." Res. Quart. 41:105-109,1970.

Thorstensson, A. "Muscle strength, fiber type and enzyme activities in man." Acta Physiiol. Scand. Supp. 443, 1976.

Thorstensson, A., Grimby, G., and Karlsson, J. "Force-velocity relations and fiber composition in human knee extensor muscles." J. Appl. Physiol. 40:12-16, 1976.

Thorstensson, A., and Karlsson, J. "Fatiguability and fiber composition of human skeletal muscle." Acta Physiol. Scand. 98:318-322, 1976.

Wenger, H. A., and Reed, A. T. "Metabolic factors associated with muscular fatique during aerobic and anaerobic work." Can. J. Appl. Sport Sci. 1:43:48, 1976.

Winter, D. A., Wells, R. D., and Orr, G. W. "Errors in the use of isokinetic dynamometers". Eur. J. Appl. Physiol. 46: 397-408, 1981.

Zohn, D. A., and Leach, R. E. "A comparison of isometric and isotonic exercises of the quadriceps after injuries to the knee." Arch. Phys. Med. Rehab. 45:571-573, 1964.

APPENDIX A

KEY

The following abbreviations have been used in the tables, appendices and text of this study:

deg/sec	Degrees/second
nm	Newton meters
fp	Foot pounds
RPM	Revolutions per minute
mm/sec	Millimeters per second
Group 1	Supervised Interval Training Based Exercise Group
Group 2	Supervised Progressive Resistance Exercise Group
Group 3	Unsupervised Home Exercise and Activity Group
PRE	Pretest score
W3	Week 3 score
POS	Posttest score
B	Injured leg
G	Uninjured leg
Q60	Peak quadriceps torque at 60 degrees/second
Q180	Peak quadriceps torque at 180 degrees/second
H60	Peak hamstrings torque at 60 degrees/second
H180	Peak hamstring torque at 180 degrees/second
QEND	Quadriceps endurance score
HEND	Hamstring endurance score
DIF	Difference score
PER	Difference score expressed as a percentage
SEM	Standard error of the mean

APPENDIX B

Interval Training Based Knee Rehabilitation Study
Information and Consent Form

Purpose:

The purpose of this study is to compare various techniques of muscle strengthening in rehabilitation of knee musculature over a period of six weeks. You will be asked to participate as a subject in one of three groups.

Testing:

Both the injured and uninjured legs will be evaluated three different times during this study, measurements will include:

a.) isokinetic peak torque of quadriceps femoris and hamstrings, measures at 60 degrees/second and at 180 degrees/second on the Cybex II dynamoneter.

b.) isokinetic endurance of quadriceps femoris and hamstrings, measured on the Cybex II dynamometer at 180 degrees/second.

Training:

You will be randomly assigned to one of the following exercise groups:

a.) Concentric progressive resistance exercise
b.) Interval training exercise
c.) Independent exercise

Subjects in groups 'a' and 'b' will be asked to attend treatment sessions three times weekly for a duration of six weeks.
Subjects in group 'c' will be given a home exercise program and will be asked to perform the exercises daily and to keep a diary of participation in any physical activities.

The researcher will conduct all testing and treatment sessions.

The data and information obtained from the study will be used for scholarly publication and discussion. All data will remain confidential and names will not be used to identify subjects.

Personal data will be freely available to all subjects in the study upon completion of the project.

The researcher agrees to answer any questions that the subject may have concerning the procedures or any other aspects of the study.

The subjects are free to withdraw participation in the study at any time and without prejudice.

Consent:

I have read the description of the proposed research and understand its potential value. I have had the opportunity to ask questions concerning this study. I am aware that I am free to withdraw from participation at any time.

Signed:________________________________ Date:______________

Witness:_______________________________ Date:______________

APPENDIX C

Calculations for Gravity Adjusted Torque

The procedure used to correct the torque scores for the effects of gravity followed the protocol outlined in the Cybex II Users Manual. During each test session, a torque reading reflecting the weight of the lower limb plus the arm of the dynamometer was taken. The investigator aligned the axis of rotation of the dynamometer with the axis of rotation of the knee, adjusted the length of the arm of the machine to the leg length of the subject and strapped the subject's thigh and shank to the dynamometer. The investigator then lifted the leg above horizontal and allowed the leg to fall into flexion at 30 degrees/second, while recording torque and range of motion. The peak torque and angle at which peak torque occured were noted.

The Cybex II printouts of peak torque for the quadriceps and hamstring muscle groups at 60 and 180 degrees/second were later analyzed using an electronic digitizer. In this manner, the x coordinate of the range of motion scale was matched with the x coordinate for the peak torque. The y coordinate was noted. This procedure was repeated twice for each of two peak torque readings. The mean value of these four readings was converted to an angle measurement by multiplying it by the digitizer scale factor–197/150.

To then determine the effect of gravity at the angle of peak torque, the formula (90 degrees - angle of peak torque - angle of peak torque of the "weight" of the leg and dynamometer arm) was used. The sine of this angle was then multiplied by the "weight" (peak torque during weighing) of the leg as determined earlier. This calculation yielded the amount of torque created by the lower leg due to gravity at the angle of peak torque during quadriceps or hamstring contraction. During quadriceps contraction, the subject exerted the torque recorded by the Cybex II plus an additional amount of torque to lift the limb against gravity. Thus, the score derived in the procedure mentioned earlier is added to the peak torque derived from the test sessions at 60 and 180 deg/sec. During hamstring contraction, the subject exerted less torque than that recorded in the test at 60 or 180 deg/sec because gravity is aiding in the descent of the limb into flexion. A final step in the conversion of raw data is multiplication of the gravity corrected score by 1.3558 to convert foot pounds to newton meters.

Example: Subject 1

Peak Torque of leg and dynamometer arm = 21 fp

Angle at which this measurement occured = 0 degrees

Quadriceps peak torque at 60 degrees/second = 215 fp

Mean y coordinate reading from the digitizer = 55.75

Mean angle at which peak torque occured = 55.75 x 197/150 = 42.45 degrees

Horizontal Variance = 90-42.45 - 0 = 47.55 degrees

Corrected torque = [(sine of 47.55)(21)] + 215 = 230.50 fp

Corrected torque in Newton Meters = 230.50 x 1.3558 = 312.36 nm

APPENDIX D

ANOVA TABLE ON POSTTEST SCORES OF THE INJURED LEG COMPARING THE THREE TREATMENT GROUPS

	Source	df	Sum of Squares	Mean Square	F
Q60B	Group	2	7899.57	3949.79	1.35
	Error	12	35191.73	2932.64	
POSQ180B	Group	2	4203.04	2101.52	1.26
	Error	12	19944.98	1662.08	
POSH60B	Group	2	657.04	328.52	0.21
	Error	12	18972.26	1581.02	
POSH180	Group	2	1434.32	717.16	0.92
	Error	12	9391.69	782.64	
POSQBEND	Group	2	621.11	310.56	2.98
	Error	12	1252.51	104.38	
POSHBEND	Group	2	108.99	54.50	0.31
	Error	12	2109.61	175.80	

APPENDIX E

ANOVA TABLE ON POSTTEST DIFFERENCE SCORES OF INJURED VS UNINJURED LEGS COMPARING THE THREE TREATMENT GROUPS

	Source	df	Sum of Squares	Mean Square	F
QADIF	Group	2	1169.16	584.58	0.68
	Error	12	10301.13	858.43	
QCDIF	Group	2	544.53	272.27	1.40
	Error	2	2329.57	194.13	
HADIF	Group	2	208.31	104.15	0.88
	Error	12	1413.87	117.82	
HCDIF	Group	2	73.67	36.84	0.37
	Error	12	1199.63	99.97	
QENDIF	Group	2	210.83	105.41	1.99
	Error	12	636.15	53.01	
HENDIF	Group	2	355.41	177.70	1.99
	Error	12	1072.47	89.37	

APPENDIX F

ANOVA TABLE ON POSTTEST DIFFERENCE SCORES EXPRESSED AS PERCENTAGES OF THE UNINJURED LEG COMPARING THE THREE TREATMENT GROUPS

	Source	df	Sum of Squares	Mean Square	F
QAPER	Group	2	290.58	145.29	0.88
	Error	12	1972.69	164.39	
QCPER	Group	2	272.29	136.14	2.30
	Error	12	710.47	59.21	
HAPER	Group	2	128.98	64.49	0.70
	Error	12	1104.48	92.04	
HCPER	Group	2	181.55	90.78	0.99
	Error	12	1096.92	91.41	
QENDPER	Group	2	1035.42	517.71	1.94
	Error	12	3196.35	266.36	
HENDPER	Group	2	7749.18	3874.59	2.43
	Error	12	19135.31	1594.61	

APPENDIX G

ANOVA TABLE ON PRETEST SCORES OF THE UNINJURED LEG COMPARING THE THREE TREATMENT GROUPS

	Source	df	Sum of Squares	Mean Square	F
PREQ60G	Group	2	6590.49	3295.24	0.97
	Error	12	40815.57	3401.30	
PREQ180G	Group	2	2975.44	1487.72	1.10
	Error	12	16217.70	1351.47	
PREH60G	Group	2	2388.12	1194.06	1.61
	Error	12	8905.97	742.16	
PREH180G	Group	2	544.73	272.36	0.57
	Error	12	5723.82	476.99	
PREQGEND	Group	2	419.95	209.98	1.80
	Error	12	1398.93	116.58	
PREHGEND	Group	2	107.93	53.96	0.32
	Error	12	2021.97	168.48	

APPENDIX H

ANOVA TABLE ON WEEK 3 SCORES OF THE UNINJURED LEG COMPARING THE THREE TREANMENT GROUPS

	Source	df	Sum of Squares	Mean Square	F
W3Q60G	Group	2	8782.44	4391.22	1.55
	Error	12	34061.36	2838.45	
W3Q180G	Group	2	2179.65	1089.83	0.72
	Error	12	18154.93	1512.91	
W3H60G	Group	2	3497.76	1748.88	1.52
	Error	12	13785.32	1148.78	
W3H180G	Group	2	2083.28	1041.64	1.44
	Error	12	8685.39	723.78	
W3QGEND	Group	2	123.74	61.87	1.42
	Error	12	523.59	43.63	
W3HGEND	Group	2	168.14	84.07	3.98 *
	Error	12	253.65	21.14	

* Statistically significant at the $p<.05$ level

APPENDIX I

ANOVA TABLE ON POSTTEST SCORES OF THE UNINJURED LEG COMPARING THE THREE TREATMENT GROUPS

	Source	df	Sum of Squares	Mean Square	F
POSQ60G	Group	2	6715.10	3357.55	1.19
	Error	12	33767.16	2813.93	
POSQ180G	Group	2	3158.17	1579.08	0.88
	Error	12	21587.63	1798.97	
POSH60G	Group	2	1605.32	802.66	0.66
	Error	12	14619.60	1218.30	
POSH180G	Group	2	1608.46	804.23	1.13
	Error	12	8567.91	713.99	
POSQGEND	Group	2	194.91	97.45	5.56 *
	Error	12	210.33	17.53	
POSHGEND	Group	2	167.94	83.97	0.72
	Error	12	1398.10	116.51	

* Statistically significant at the $p<.05$ level

APPENDIX J

TABLES OF ANOVA WITH REPEATED MEASURES ON THE UNINJURED LEG COMPARING PRETEST, WEEK 3 AND POSTTEST SCORES

Variable	Source	df	Sum of Squares	Mean Square	F
Group 1 Q60	Subject	4	46014.63	11503.66	0.30
	Time	2	78.09	39.04	
	Interaction	8	1028.66	128.58	
Group 2 Q60	Subject	3	14677.84	4892.61	2.86
	Time	2	219.24	109.62	
	Interaction	6	230.01	38.33	
Group 3 Q60	Subject	5	45352.99	9070.60	0.31
	Time	2	81.91	40.96	
	Interaction	10	1339.95	133.99	
Group 1 Q180	Subject	4	20800.20	5200.05	1.28
	Time	2	543.87	271.93	
	Interaction	8	1698.95	212.37	
Group 2 Q180	Subject	3	5088.68	1696.23	2.96
	Time	2	180.70	90.35	
	Interaction	6	183.38	30.56	
Group 3 Q180	Subject	5	25655.07	5131.01	0.35
	Time	2	179.29	89.65	
	Interaction	10	2533.98	253.40	

* Statistically significant at the $p<.05$ level

APPENDIX J (continued)

TABLES OF ANOVA WITH REPEATED MEASURES ON THE UNINJURED LEG COMPARING PRETEST, WEEK 3 AND POSTTEST SCORES

Variable	Source	df	Sum of Squares	Mean Square	F
Group 1 H60	Subject	4	20734.83	5183.71	
	Time	2	226.62	113.31	1.88
	Interaction	8	481.89	60.24	
Group 2 H60	Subject	3	1792.53	597.51	
	Time	2	468.89	234.45	2.95
	Interaction	6	476.55	79.43	
Group 3 H60	Subject	5	12746.81	2549.36	
	Time	2	609.44	304.72	2.83
	Interaction	10	1078.26	107.83	
Group 1 H180	Subject	4	11381.26	2845.32	
	Time	2	73.56	36.78	0.42
	Interaction	8	698.94	87.37	
Group 2 H180	Subject	3	696.97	232.32	
	Time	2	172.27	86.13	1.16
	Interaction	6	445.63	74.27	
Group 3 H180	Subject	5	8956.34	1791.27	
	Time	2	1308.44	654.22	8.20 *
	Interaction	10	797.99	79.80	

* Statistically Significant at the $p<.05$ level

APPENDIX J (continued)

TABLES OF ANOVA WITH REPEATED MEASURES ON THE UNINJURED LEG COMPARING PRETEST, WEEK 3 AND POSTTEST SCORES

Variable	Source	df	Sum of Squares	Mean Square	F
Group 1 QGEND	Subject	4	747.81	186.95	
	Time	2	75.96	37.98	0.73
	Interaction	8	416.52	52.06	
Group 2 QGEND	Subject	3	375.28	125.09	
	Time	2	143.14	71.57	3.57
	Interaction	6	120.38	20.06	
Group 3 QGEND	Subject	5	274.15	54.83	
	Time	2	11.68	5.84	0.29
	Interaction	10	198.72	19.87	
Group 1 HGEND	Subject	4	999.86	249.96	
	Time	2	54.38	27.19	0.47
	Interaction	8	462.90	57.86	
Group 2 HGEND	Subject	3	610.73	203.58	
	Time	2	27.31	13.65	0.15
	Interaction	6	552.60	92.10	
Group 3 HGEND	Subject	5	613.51	122.70	
	Time	2	110.33	55.16	1.27
	Interaction	10	434.12	43.41	

* Statistically significant at the $p < .05$ level

APPENDIX K

TABLES OF ANOVA WITH REPEATED MEASURES ON GROUPS 1 AND 2 (COMBINED) COMPARING PRETEST, WEEK 3 AND POSTTEST SCORES

Variable	Source	df	Sum of Squares	Mean Square	F Ratio
Q60	Subject	8	72632.71	9079.09	
	Time	2	129.08	64.54	0.45
	Interaction	16	2284.92	142.81	
Q180	Subject	8	27556.38	3444.55	
	Time	2	687.31	343.66	
	Interaction	16	1919.58	119.97	
H60	Subject	8	23897.95	2987.24	
	Time	2	653.13	326.57	5.22 *
	Interaction	16	1000.82	62.55	
H180	Subject	8	12630.42	1578.80	
	Time	2	151.15	75.58	0.98
	Interaction	16	1239.25	77.45	
QGEND	Subject	8	1162.57	145.32	
	Time	2	190.70	95.35	2.70
	Interaction	16	565.29	35.33	
HGEND	Subject	8	3158.56	394.82	
	Time	2	31.27	15.63	0.29
	Interaction	16	867.16	54.20	

* Statistically significant at the $p<.05$ level

APPENDIX L

INDEPENDENT SAMPLES t TEST FOR ATTENDANCE OF GROUPS 1 AND 2

Group	$\bar{x} \pm$ SEM	t Ratio
Group 1	17.00 ± 0.45	0.88
Group 2	16.00 ± 0.29	

APPENDIX M

ANOVA TABLE ON AGE OF SUBJECTS COMPARING THE THREE GROUPS

	Source	df	Sum of Squares	Mean Square	F
AGE	Group	2	253.88	126.94	0.97
	Error	12	1567.45	130.62	

APPENDIX N

MEAN PEAK TORQUE OF THE INJURED LEG ± SEM (FOOT POUNDS)

VARIABLE	GROUP 1	GROUP 2	GROUP 3
PREQ60	147.35 ± 28.78	127.69 ± 14.58	176.76 ± 16.32
POSQ60	138.72 ± 19.33	129.43 ± 11.96	168.36 ± 18.22
PREQ180B	102.21 ± 18.03	93.26 ± 11.00	114.55 ± 11.52
POSQ180G.	101.85 ± 14.04	97.69 ± 10.70	124.99 ± 13.59
PREH60B	81.04 ± 16.56	67.23 ± 5.48	91.18 ± 7.04
POSH60B	88.93 ± 15.28	83.85 ± 8.40	95.81 ± 12.65
PREH180B	62.02 ± 11.26	51.02 ± 2.60	71.86 ± 6.32
POSH180B	67.04 ± 9.43	60.53 ± 7.03	77.95 ± 9.55

APPENDIX O

MEAN PEAK TORQUE OF THE UNINJURED LEG ± SEM (FOOT POUNDS)

VARIABLE	GROUP 1	GROUP 2	GROUP 3
PREQAG	171.40 ± 21.55	156.59 ± 15.68	194.15 ± 18.23
W3QAG	170.76 ± 20.64	149.03 ± 14.14	193.29 ± 15.92
POSQAG	174.61 ± 19.73	151.46 ± 15.17	190.47 ± 16.15
PREQ180G	113.99 ± 13.54	104.78 ± 9.35	129.83 ± 11.71
W3Q180G	124.43 ± 14.57	111.77 ± 7.87	133.98 ± 12.76
POSQ180G	121.84 ± 14.70	108.74 ± 9.47	135.29 ± 14.54
PREH60G	85.78 ± 13.17	73.29 ± 4.79	96.50 ± 6.06
W3H60G	90.56 ± 14.78	79.39 ± 5.33	106.84 ± 9.64
POSH60G	92.63 ± 13.61	84.57 ± 7.17	103.28 ± 11.00
PREH180G	64.52 ± 10.25	56.13 ± 2.06	67.03 ± 5.66
W3H180G	68.44 ± 10.68	59.48 ± 4.73	80.74 ± 8.52
POSH180G	65.77 ± 10.47	62.98 ± 5.01	79.97 ± 8.50

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