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COMPARISON OF THE EFFECTIVENESS OF VARIABLE AND SEMI-ACCOMMODATING RESISTANCE TRAINING IN QUADRICEP AND HAMSTRING STRENGTHENING IN WOMEN

by

© ANGELA MARIE KOCHAN

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF Master of Science

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SPRING 1986

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled COMPARISON OF THE EFFECTIVENESS OF VARIABLE AND SEMI-ACCOMMODATING RESISTANCE TRAINING IN QUADRICEP AND HAMSTRING STRENGTHENING IN WOMEN submitted by ANGELA MARIE KOCHAN in partial fulfilment of the requirements for the degree of Master of Science.

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Date March 12, 1986

Abstract

In order to ascertain the effects of variable and semi-accommodating resistance exercise on muscular strength, forty sedentary women, ranging from eighteen to thirty years of age, were randomly assigned to exercise on the Nautilus variable resistance machine or on the Hydra-Gym semi-accommodating resistance machine and to a control group. The quadriceps and hamstrings were exercised three days a week for a period of six weeks, and were tested before and after the six week period on peak muscle torque by means of a Cybex II isokinetic dynamometer. Measurements of peak torque were obtained at a velocity of 0.524 r/s (30 deg/s). Analysis of covariance was applied to the data obtained on peak torque measures. Results indicated that both the Hydra-Gym and Nautilus training groups significantly ($p<.001$) increased peak muscle torque. No significant differences were observed when comparing the Hydra-Gym training group to the Nautilus training group in peak muscle torque in the quadriceps. However, the results showed that the group training on the Nautilus machine was significantly superior ($p<.05$) to the group training on the Hydra-Gym machine for increasing peak muscle torque in the hamstring muscle group.

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CHAPTER 1

STATEMENT OF THE PROBLEM

Introduction

Resistance exercise has been widely accepted as a training modality for the development and maintenance of strength. Resistance exercise is categorized as constant resistance, accommodating resistance, and variable resistance (41). Isotonic exercise (constant resistance) involves muscular contractions against a device which provides a load remaining at a fixed level (13, 40, 48, 51). Because of the muscle length/joint angle relationship, neither the force of contraction nor the resistance provided by the load is maximum throughout the full range of motion. This relationship limits the muscle's ability to produce maximum torque (during isotonic exercise) only at the weakest point in the range of motion (9, 12, 13, 48).

Accommodating resistance attempts to overcome the limitations of isotonic exercise. One type of accommodating resistance training is isokinetic exercise. Isokinetic exercise develops near maximal loads on a muscle at a constant angular velocity throughout the full range of motion at a mechanically fixed rate of velocity (1, 3, 5, 10, 13, 23, 42, 50, 52). Isokinetic exercise is performed by means of an isokinetic device which involves concentric (miometric) muscle contractions (23, 34, 52). The load against which a muscle or muscle group contracts, purportedly offers resistance directly proportional to the muscles dynamic tension developing capacity (1, 8, 24, 39, 40).

Since the development of isokinetic exercise, new and advanced forms of resistance exercise systems have been designed. Omnikinetics is one of the most recent advances in resistance exercise systems, and was introduced in the mid-seventies by the manufacturers of Hydra-Gym equipment. Omnikinetics is referred to as semi-accommodating resistance training which emphasizes reciprocal concentric muscle work throughout the full range of motion (27). The principle of omnikinetic resistance is based upon the patented Hydra-Fitness hydraulic cylinder (14). The hydraulic cylinder provides self-accommodating, variable resistance, at the velocity the user is capable of generating (14). This is made possible by the use of adjustable valve settings on the hydraulic cylinder. The Series III machine (which was used in the present study) features hydraulic cylinders with valve settings of "1 through 6". A valve setting of "5 or 6" is used to train for strength (14).

Omnikinetic exercise is similar to isokinetic exercise in that it involves concentric (miometric) muscle contraction, utilizing both agonist and antagonist muscles during the same exercise set. However, omnikinetic exercise machines allows for minimal variability in velocity of movement, whereas true isokinetic exercise machines involves constant velocities.

In 1970, the Nautilus Sports/Medical Industries marketed their first variable resistance exercise machine (7). The Nautilus equipment was designed in an attempt to overcome the limitations of constant resistance exercise, more specifically, the barbell. The Nautilus equipment purports to provide resistance correlated to the mechanical efficiency of the joint throughout the full range of motion (7). This is accomplished by the use of the patented Nautilus cam (7). The Nautilus cam is designed to compensate for the variations in force as movement occurs by changing the length of the moment arm. Although the load that is lifted during the exercise remains constant, the effective resistance will be increased or decreased (28, 35, 41). Simply, when the limb is in a position where the muscles can exert maximal force, the radius of the cam will be large. As the limb moves into a position where the available strength declines, the radius of the cam will become smaller, thus decreasing the resistance in proportion to the declining strength (35). However, because of variations in limb length, and the muscle length/joint angle relationship, from individual to individual, the greatest resistance may not be where the muscle can exert its' greatest force.

A review of the literature reveals that resistance exercise machines are used as training modalities for the development of muscular strength. The establishment of training programs using the various types of equipment, for the development of muscular strength, should be beneficial if the instructions for completing the exercises are followed.

The Problem

The purpose of this study was to compare the Nautilus leg flexion and leg extension variable resistance machines, with the Hydra-Gym unilateral quadricep/hamstring omnikinetic machine, in their ability to affect changes in peak muscle torque, as measured by the Cybex II isokinetic dynamometer, at an angular velocity of 0.524 radians per second (r/s) (30 degrees per second (deg/s)).

Secondly, to compare the effectiveness of the Hydra-Gym and Nautilus training machines using the training protocols recommended by the manufacturers of the equipment.

Justification for the Study

Research has demonstrated that increases in muscular strength are possible with the Nautilus exercise machines (4, 19, 41, 43, 48). The manufacturers of the Nautilus equipment claims that it meets all the requirements for a "perfect" form of exercise. In reviewing the published literature involving the Nautilus exercise equipment, the research studies have been few in number and limited to adult males. To date, no published research studies have been found involving female participants, in regards to exercising on the Nautilus equipment, for increasing muscular strength.

A review of the recent research involving Hydra-Fitness omnikinetic training has been shown to develop muscular strength in the quadricep and hamstring muscle groups (22, 26). However, after a comprehensive search of the published literature, most of the Hydra-Fitness studies have been produced by the manufacturers themselves or by associated company researchers. Those research findings may or may not have been found because of a bias towards the Hydra-Fitness equipment.

Since both the Nautilus and Hydra-Fitness exercise machines have been proven to develop muscular strength, there is a need for comparative research to determine which machine will produce more significant strength gains.

Hypotheses

The following hypotheses were tested in this study.

1. Variable resistance training (Nautilus) and omnikinetic training (Hydra-Gym) do not differ in their ability to affect changes in peak muscle torque.
2. Training with the Nautilus and Hydra-Gym equipment will produce significant changes in peak muscle torque over a period of six weeks.

Limitations

1. There was no control over the time of day in which the subjects exercised or were tested.
2. An attempt was made to equate the Hydra-Gym and Nautilus training groups in terms of number of sets, repetitions, and work load.
3. The subjects motivation to perform while exercising or during testing sessions could not be controlled. However, verbal encouragement for maximal performance was given to each subject by the tester during the training and testing sessions.

Delimitations

1. The study was delimited to sedentary female volunteers, with no significant history of lower limb pathology, ranging between the ages of 18 - 30 years of age.
2. Subjects were told that they could not participate in any athletic activities during the six week experimental training period.
3. The training program was delimited to 3 days/week, for a period of six weeks (18 training sessions). The subjects were instructed to train every second day. However, when this was not possible for them, the only restriction was that they could not train three days consecutively.

Definition of Terms

1. Muscular strength - the force that a muscle or muscle group can exert against a resistance in a single maximal voluntary contraction (1, 20).
2. Torque - the product of a force times its' perpendicular distance (to a lever arm) which is rotating or tends to rotate about an axis of rotation. Torque is measured in units of force multiplied by the distance (foot-pounds or Newton-metres) (23, 33, 38).
3. Peak torque - the highest point generated on the isokinetic torque curve.
4. Isometric contraction - a muscular contraction which occurs against a load that prevents external movement and offers resistance proportional to the muscle's tension developing capacity, therefore resulting in no apparent change in muscle length or in skeletal movement (13, 21, 40).
5. Concentric (miometric) contraction - a muscular contraction in which the muscle length decreases.
6. Eccentric (plyometric) contraction - a muscular contraction in which the muscle length increases.
7. Isokinetic contraction - one in which a muscle or group of muscles contract near maximally at a constant angular velocity throughout the full range of motion, at a mechanically fixed rate of velocity (10, 21, 33, 36, 52).

8. Variable resistance - resistance provided by a device increases or decreases throughout the range of motion according to the advantage or disadvantage of the biomechanical contractile properties of the muscle, and with a constant load.
9. Omnikinetics - a form of resistance training which attempts to accommodate the resistance to the mechanical advantage of the skeletal lever arm, at varying speeds of movement, throughout the full range of motion.
10. Agonist - those muscles most directly involved in a muscle contraction.
11. Antagonist - those muscles which work in opposition to the agonist muscle.
12. Hypertrophy - an adaptive response to strength training where there is an increase in the size of the muscle cell.
13. Double positive resistance - the reciprocal action of the opposing muscle groups (agonist and antagonist) during an exercise (27).

CHAPTER 2

REVIEW OF LITERATURE

To date, very few comparative studies have been published utilizing the Nautilus resistive equipment and the hydraulic resistive equipment which were used in this study. Therefore, it was necessary to review the available literature regarding both types of equipment, in order to develop suitable training programs for this study.

Isokinetic testing has been widely used in research, clinical settings, and for the testing of athletes, since it was first reported by Hislop and Perrine in 1967 (13). Since this time, several different isokinetic testing protocols have been developed and it becomes necessary to review the literature in the area of isokinetic testing, in order to determine an appropriate test protocol for this study.

The review of literature will be organized under the following headings: variable resistance exercise, omnikinetics, measuring isokinetic muscle torque, and, factors affecting isokinetic testing.

Variable Resistance Exercise

Variable resistance exercise involves concentric and eccentric contractions of the muscles or muscle group. As movement occurs, the resistance will theoretically change in accordance to the mechanical efficiency of the involved joint. The variable resistance equipment that was used in this study is manufactured by Nautilus/Sports Medical Industries. The Nautilus machines are purportedly designed to provide resistance that automatically varies in proportion to the changing strength of the muscles, thus allowing for maximal contraction of the muscles throughout the full range of movement (19). However, research involving the Nautilus leg extension machine has demonstrated that the resistance progressively increases throughout the range of movement, and therefore does not duplicate the normal force curve that is generated by a muscle (49).

To date, research has shown that training with Nautilus equipment will produce changes in muscular strength. Pipes (41) compared variable resistance (VR) and constant resistance (CR) training procedures in their ability to affect changes in muscular strength, body composition and anthropometric measures. Men between 18 - 26 years of age, trained three days/week, 45 minutes/day, for a period of ten weeks. Both groups trained at 75% of their one repetition maximum for eight repetitions, for three sets. Results indicated that both training programs increased strength significantly ($p<.05$). However, the CR group demonstrated significant increases in strength over the VR group when strength was assessed by CR procedures. Further, the VR group showed significant increases ($p<.05$) in strength over the CR group when strength was assessed by VR procedures.

Pipes suggested that strength training is specific to the type of movement that is performed.

Coleman (4) compared the Nautilus training machine with the Universal Gym equipment to examine changes in muscular strength, body composition and anthropometric measurements. College aged males trained three days/week, 40 minutes/day, for a period of ten weeks. Subjects in the Universal Gym group performed two sets of ten and eight repetitions respectively, while the Nautilus group performed one set of ten to twelve repetitions. The weight was progressively increased when the subjects could perform more than the maximum number of repetitions stated. Results indicated that both training programs produced significant increases in muscular strength ($p<.05$), with no significant difference between training programs. Coleman concluded that both the Universal and Nautilus equipment are similarily effective for increasing muscular strength.

Coleman (4) and Pipes (41) tend to agree that the Nautilus training equipment is an acceptable training modality for affecting changes in muscular strength.

Omnikinetics

Omnikinetics was introduced by the manufacturers of Hydra-Gym equipment in 1974 (14). Hydra-Fitness omnikinetic exercise machines provide double concentric (positive) resistance at any joint angle and at varying speeds of the limb throughout the full range of movement (14). The

Hydra-Gym equipment provides reciprocal resistance through the use of hydraulic cylinders with adjustable valve settings. "The valves on the machine varies the resistance to lever arm movements by changing the aperture size through which hydraulic fluid must flow as the lever arm moves" (27:II-9). The velocity in which the limb is moving against the resistance is determined by the contractile properties of the user's muscles. Optimal resistance is offered with each repetition providing that the lever arm is moved with maximal effort.

The research, conducted in the area of omnikinetic training, has shown to produce increases in muscular strength. LaGasse (22) studied the effect of omnikinetic training on peak torque utilizing the Hydra-Fitness knee flexion/extension machine. Twenty women, between the ages of 21 to 26, participated in the study during the fall semester of university. For treatment 1, subjects executed knee extension, and for treatment 2, subjects performed knee extension and flexion. Both treatments were performed with the hydraulic cylinder set at a resistance setting of 4. Results showed a significant increase of 11.4% in muscle torque output, and an increase of 42.9% and 32.1% in electromyographical (EMG) activity of the vastus lateralis and vastus medialis muscle, when knee extension was preceeded by concentric flexion of the hamstring muscle group. LaGasse concluded that strength would develop quicker using reciprocal concentric muscle work in comparison to exercise involving both concentric and eccentric contractions, in terms of muscle torque output and EMG activity.

Lee (25) also reported a significant increase in muscular strength and power using Hydra-Fitness training equipment. The subjects trained every second day for a total of 28 workouts (seven and a half weeks). The machines used featured hydraulic cylinders with settings of 1 through 6. The subjects performed three sets using 1-5-3 resistance settings. The work:relief ratio for the first four weeks was 20 seconds:40 seconds (1:2), and for the last four weeks was 30 seconds:50 seconds (1:1.67). Muscular strength and power was assessed isokinetically at velocities of 30 deg/s (0.524 r/s) and 60 deg/s (1.048 r/s) for strength, and at 180 deg/s (3.14 r/s) for power. Both muscular strength and power increased at their testing velocities after training on the Hydra-Fitness equipment.

The research involving omnikinetic training is limited in the area of muscular strength. In reviewing the literature to date however, omnikinetic training would seem to produce changes in muscular strength if a prescribed training program was followed.

Measuring Isokinetic Muscle Torque

The isokinetic measuring device that was used in this study is the Cybex II isokinetic dynamometer. The Cybex II system has been widely used as a testing modality for research, clinical testing, and for rehabilitation. Many test protocols have been developed for testing muscular strength of the knee flexors and knee extensors using the Cybex II dynamometer. The manufacturers of the Cybex II equipment suggest that non-athletes should be tested for strength at a velocity of 60 deg/s (1.048 r/s). Other researchers (11, 25, 34, 49) have measured strength at velocities as low as 0.524 r/s (30 deg/s). It is important to note that the term strength is defined differently for isokinetic testing when compared to the physiological definition, as previously stated. In using the Cybex II isokinetic dynamometer, "strength is defined as maximum slow-speed torque capability" (15:5).

The Cybex II isokinetic dynamometer consists of a lever arm which can be adjusted to the length of the limb being tested. The rotational axis of the dynamometer should be aligned with the anatomical axis of the joint being tested (32). The lever arm is attached to the limb being tested, and is moved at a preselected constant velocity. The lever arm is prevented from surpassing a preselected constant velocity by a mechanical electromotor device which automatically adjusts the voltage for variations in torque (52). Any additional effort will result in increased resistance rather than an increase in acceleration. A pen recorder is attached to the isokinetic device and provides a continuous curve of the torque produced over the full range of motion (50). The Cybex manufacturers refers to the pen recorder as a Dual-Channel Strip Chart Recorder. It allows for the selection of a torque range scale, paper speed, position angle degree scale, position angle calibration, and damp settings.

For knee flexion/extension in non-athletes, the manufacturers suggest that a torque range scale of 180 ft-lbs should be used, with the position angle scale set at 150 degrees, and the damp set at 2. For tests that require only peak torque measurements, the chart speed should be set at 5 mm/s. The Dual Channel Recorder simultaneously records the generated torque and the range of motion of the movement. On one channel, the torque curve generated by the working muscle group is recorded, as transmitted from a strain gauge inside the dynamometer (52). On the second channel, the range of motion is recorded, as transmitted from a potentiometer located on the input shaft of the dynamometer (52). The torque (in foot-pounds) is interpretated from the Dual Channel Recorder readout with a Cybex II Chart Data Card. Computers can also be linked with the Cybex II device in order to aid in data processing.

Factors Affecting Isokinetic Testing

The Cybex II isokinetic dynamometer has been found to be both reliable and valid for test measurements of torque, work, and power (24, 33). Moffroid et al (33) reported a test-retest reliability of r=0.995 and a reliability of r=0.999 for predicted to obtained torque values for various lever arm positions. However, standardization of test protocols are necessary in order to compare valid interpretations of the isokinetic data presently being published. There are several factors which will affect the graphic torque readouts when testing the quadriceps and hamstrings isokinetically. These factors will be discussed under the following headings: stabilization, knee alignment, body position, warm up, damp, and, torque overshoot.

Stabilization

When evaluating the quadriceps and hamstrings on the Cybex II isokinetic dynamometer, the thigh as well as the torso must be stabilized in order to obtain precise torque values.

Johnson (17) devised a restraint system that stabilized the hip and trunk during quadricep/hamstring evaluation on the Cybex II. The restraint system included a shoulder and a lap belt harness. It was used to prevent extra movements by keeping the hips down and the trunk stationary. Subjects were tested at 120 and 240 deg/s (2.10 r/s and 4.20 r/s) for knee extension and flexion exercise. Results indicated that the quadriceps generated less torque and the hamstrings generated more torque when the restraint system was not used. Johnson concluded that the quadriceps and hamstrings will be better isolated with the use of a restraint system.

Other researchers (2, 11, 16, 24, 34, 44, 46) localized the muscle contraction strictly to the quadricep and hamstring muscle groups by stabilizing the shoulders, hips, and thighs. This will reduce excess movements of the body which may affect the generated torque graph readout.

Knee Alignment

In Cybex studies, maintenance of the alignment of the rotational axis of the dynamometer arm with the axis of rotation of the knee joint was extremely important (11, 33, 37). Changes in alignment will affect the accuracy of the measurement of the moment of force generated by the mechanical advantage of the muscle group in moving the resistance arm (37). Therefore, it is necessary to maintain proper knee alignment in order to obtain accurate measurements for the generated torque curve.

Body Position

In the seated testing position for knee flexion and knee extension, the body must be positioned so that the back is stabilized against the chair, and so the knee is allowed to move through full flexion and extension during the exercise. Back pads can be used to allow for differences in femur length.

Low speed isokinetic torque and isometric force readings have been found to be similar (33, 37). Therefore, the importance of maintaining a constant hip angle in isometric exercise may also pertain to low speed isokinetic testing. Currier (6) tested for maximal isometric contraction of the knee extensor muscles with the hips positioned at angles of 100, 110, 120, and 130 degrees to the horizontal. The results showed that knee extensor force with the hip positioned at 110, 120, and 130 degrees was significantly greater ($p<.01$) than the force generated when the hip was positioned at 100 degrees. The findings implied that hip position is important in order to take advantage of the lengthening of the knee extensors which crosses the hip joint. If the knee extensors are placed in a lengthening position, it will enable the muscles to exert more force at the knee joint.

In Cybex studies involving the knee extensor muscles, the hips were flexed from 120 degrees to 100 degrees (with 180 degrees being complete hip extension) (8, 31, 34, 37). In reviewing the literature on body positioning for isokinetic testing, results suggest that hip position may influence the force exerted during maximal knee extensions.

Warm Up

Maximal and submaximal contractions are commonly used for warm up in isokinetic testing. The purpose of eliciting a warm up is to familiarize the subject with the isokinetic machine, and to prevent any discomfort or injury during the exercise period.

Johnson and Siegel (18) performed a reliability study of isokinetic movement of the knee extensor muscles. It was conducted over three consecutive days at a velocity of 180 deg/s (3.14 r/s). Reliability coefficients for test measurements ranged from .93 to .99. They concluded that three submaximal contractions followed by three maximal contractions need to be performed before stable measures occur.

Mawdsley and Knapik (31) examined changes in peak torque of the knee extensor muscles on the Cybex II isokinetic dynamometer. Sedentary subjects, without isokinetic testing experience, participated in the study. The subjects performed one maximal isokinetic contraction six times at 0.524 r/s (30 deg/s), and received no warm up prior to testing. Three sessions of six maximal contractions were performed at two week intervals. Results showed a significant interaction effect between trials and sessions ($p<.001$), indicating that the pattern of the scores within the three sessions was significantly different. No significant differences were found in mean peak torque across trials or sessions. In session 1, significant differences were found within trials ($p<.05$), and between trial 1 and 3 ($p<.05$). In view of this finding, Mawdsley and Knapik suggest that if subjects without isokinetic testing experience are to be tested in one session only, at least one maximal trial should occur prior to testing to ensure replicable strength measures.

Mawdsley and Croft (30) studied the effects of three submaximal contractions (30 deg/s (0.524 r/s)) prior to isokinetic testing of maximal contractions. Physically active subjects, who were inexperienced in Cybex testing, participated in the study. Group 1 performed three submaximal isokinetic contractions immediately prior to testing; group 2 did not perform submaximal contractions. Testing consisted of six trials with a trial consisting of one maximal isokinetic contraction. Results indicated a significant interaction (p<.001) between trials and groups. Trial 1 of group 1 was also significantly different from trial 1 of group 2 (p<.01). The findings also indicated that the performance of submaximal contractions prior to isokinetic testing appeared to prevent discomfort during testing, however, the three submaximal contractions did not allow for an appropriate type of practice to occur to ensure replicable test trials. Mawdsley and Croft concluded that at least one maximal contraction is necessary before measurements will be stable, and that pre-test submaximal contractions need to be performed to help prevent discomfort during isokinetic testing.

Mawdsley and Croft (29) also studied the effects of submaximal contractions (30 deg/s (0.524 r/s)) prior to isokinetic testing, in physically active subjects who had prior experience in isokinetic testing. The results demonstrated that the performance of three submaximal contractions was adequate to prevent discomfort during the test session. There was no significant differences in the mean peak torque of maximal isokinetic contractions of the knee extensor muscles either in the presence or absence of submaximal contractions, within each group, and among trials, at the .05 level. Mawdsley and Croft concluded that submaximal contractions will not influence mean peak torque, when subjects (experienced in isokinetic testing) perform maximal isokinetic contractions.

It would be plausible to suggest that both maximal and submaximal contractions are necessary to produce reliable and valid measures and to prevent discomfort during isokinetic exercise, with subjects who are unfamiliar with isokinetic testing.

Damp and Torque Overshoot

The damp settings on the Cybex II recorder may be a potential source of error in the graphic torque readout. Damp settings are used to reduce the energy oscillations (torque overshoot) in the graphically recorded torque measurements (16). Torque overshoot appears as an initial spike in the torque output curve when the subject reaches the machine's preset velocity (45, 47). The Cybex II strip chart has five damp settings ranging from 0 to 4, with 4 representing the highest damp setting (15). As the damp setting increases, the magnitude of the generated torque curve will decrease and will also be displaced to the right (47). The manufacturers of the Cybex II equipment suggest that a damp setting of 2 should be used for isokinetic knee flexion/extension testing. Coyle et al (5:1438) state that "a damp setting of 2 will generate a smooth reliable torque tracing by averaging torque oscillations within a period of approximately 50 ms".

Sapega et al (45) studied the nature of torque overshoot in Cybex II isokinetic dynamometry. They stated that torque overshoot and secondary oscillations that appear in Cybex torque readouts represent the forces associated with velocity fluctuations of an initially overspeeding limb-lever system. They suggest that a damp setting of 2 is best for low speed (0.524 r/s (30 deg/s)) testing because it will reduce the torque curve only to a small extent. However, damp settings should not be used in high speed testing (3.14 r/s (180 deg/s) or greater) because the overshoot will be spread over a greater portion of the torque curve, thus reducing the ability of the damping curcuit to suppress the overshoot selectively.

CHAPTER 3

METHODS AND PROCEDURES

Subjects

The sample consisted of 47 sedentary women, with no significant history of lower limb pathology, between 18 and 30 years of age (with a mean age of 22.2 years). Each participant was fully informed of all risks and stresses associated with this project and they were asked to sign a written consent to participate in the study (Appendix G). The subjects were also informed that they could not participate in any athletic activities during the six week training program.

The subjects volunteered to participate in an eight week training program, however, due to subject attrition, the training program was decreased to six weeks. The subjects were randomly selected into three groups, followed by random assignment of treatments to groups. In the initial program, 16 subjects trained on the Hydra-Gym omnikinetic machine, 16 subjects trained on the Nautilus exercise machine, and 15 subjects did not perform any exercise, thus serving as a control group. However, during the course of the training program, seven subjects dropped out of the study leaving 13 subjects in both the Nautilus and Hydra-Gym training groups, and 14 subjects in the control group.

Methods and Materials

The quadriceps and hamstrings were exercised using either the Nautilus or Hydra-Gym resistance training machines, and were tested for peak muscle torque, before and after the training program by means of a Cybex II isokinetic dynamometer. To localize the contraction to the proper muscle group in the testing procedure, the subjects were securely strapped across the chest, pelvis, and proximal to the patella. The subjects were seated with the hips flexed at approximately 105 degrees (180 degrees equals full hip extension). The axis of rotation of the dynamometer was aligned with the lateral femoral condyle of the knee joint. The lever arm was attached to the tibia at the top of the medial malleoli, allowing for active dorsi flexion of the ankle. Due to variations in femoral lengths, back rests were used (if needed), to maintain a standard distance (one and one half inches), between the edge of the table and the lateral femoral condyle of the knee joint.

The Cybex II was calibrated according to the Cybex manual (15). Peak muscle torque was measured by means of an electronic transducer called the Cybex II Dual Channel Recorder, which gives a graphic readout of the generated torque curve over the entire range of movement. A damp setting of "2" was used, with the chart speed set at 5 mm/s. The torque range scale was set at 180 ft-lbs, and the position angle scale was set at 150 degrees. The effect of gravity on the generated torque recordings were not corrected for since the effect due to gravity would remain constant within and between the pre-test and post-test measures, on both flexion and extension movements.

Testing Procedure

Two isokinetic tests were administered, one before and one after the training period. The Cybex II isokinetic dynamometer was used to measure peak muscle torque (ft-lbs) of the quadriceps and hamstrings. For the purpose of analysis, torque readings were recorded in ft-lbs and then converted to Newton-metres (N-m). Peak muscle torque was measured at an angular velocity of 0.524 r/s (30 deg/s). The subjects warmed up using three submaximal and three maximal contractions at 0.524 r/s and then rested for approximately two minutes prior to testing. One set of five maximal knee flexions and extensions were performed from ninety to zero degrees (zero degrees equals full knee extension) using the dominant leg. The dominant leg was defined as the limb which the subject would use when kicking a ball. Peak torque was obtained by recording the highest value from the last four curves from the Dual Channel Recorder readout with a Cybex II Chart Data Card (Appendix F). The first torque curve was omitted in order to avoid incorrect torque output, which may result due to the subjects unfamiliarity with the Cybex II dynamometer. The subjects were encouraged to exert maximal force throughout the 90 degree arc of movement.

Training Program

The subjects trained on either the Hydra-Gym unilateral quadricep/hamstring machine or on the Nautilus leg extension and leg flexion machines, three times a week for a period of six weeks. The control group did not exercise for the duration of the six week program.

The subjects in the Hydra-Gym group trained on one machine that exercised the quadriceps and hamstrings in the same set. In performing the exercise, the subjects alternately moved the legs in opposite directions as quickly as possible, that is, one leg performed extension while the other leg moved through flexion. The subjects trained for strength by performing four sets of repeated repetitions for 20 seconds. Forty seconds of rest was allowed between each set. The resistance setting was set at 5 for the first four weeks, and at 6 for the last two weeks of training. The subjects attempted to progressively increase the number of repetitions for each 20 second work interval. The total time of work for the Hydra-Gym training group was 80 seconds, per training session.

The subjects in the Nautilus training group performed one set of repetitions on two separate machines. One machine exercised the quadriceps, and the second machine exercised the hamstrings. The subjects selected a resistance that permitted 8 to 12 repetitions in one set. The resistance was increased by five pounds when more than 12 repetitions could be performed. One repetition took approximately five seconds to perform. The concentric phase of contraction took two seconds to perform, and the eccentric phase of contraction was performed in three seconds, thus accentuating eccentric contractions. In performing 8 to 12 repetitions, the total time of work for the Nautilus training group was 80 to 144 seconds, per training session.

In both training programs, the subjects worked through at least a 90 degree range of motion, and they were encouraged to perform as many repetitions as possible in the work interval. Both training programs included a five to ten minute warm up of passive stretching exercises immediately prior to training. Each subject kept records of their training program in regards to the date, resistance setting, and number of repetitions performed (Appendix I). In order to assure consistency of performance, the subjects were instructed and supervised in the Hydra-Gym and Nautilus training techniques and procedures for exercise performance on the leg flexion and leg extension machines.

Statistical Analysis

A pooled regression analysis of covariance was applied to the data to determine whether there was a statistical significant difference between treatment groups and trial measures, and, to detect for the differences in pre-test group means. The alpha error was set at the .05 level of significance. The .01 and .001 levels were reported if the data was found to be significant at the corresponding levels.

CHAPTER 4

RESULTS AND DISCUSSION

Results

A pooled regression analysis of covariance was employed on the data from this study to determine significance between groups and trial measures since subject attrition and/or sampling error resulted in unequal group means on the pre-test scores. A preliminary analysis of covariance, to assess individual group regression lines, between pre-test and post-test measures, indicated that the regression lines were sufficiently homogeneous to warrant using a regular analysis of covariance, based on a pooled regression estimates.

The mean torque values and the mean effects corrected for the covariate for the data generated during knee extension and knee flexion are presented in Tables I and II respectively. An examination of the pre-test and post-test group means for knee extension (as illustrated in Figure 1) indicated that the Hydra-Gym and Nautilus training groups significantly increased ($p<.05$) in peak torque by 31.69 and 36.27 percent respectively. The control group experienced a

4.31 percent decrease in peak torque, however, this decrease was not significant within the boundries of the .05 level. Similar results were found for knee flexion. Both the Hydra-Gym and Nautilus training groups significantly increased ($p<.05$) in peak torque by 16.42 percent and 23.80 percent respectively. The control group decreased in peak torque by 8.46 percent, however, this decrease was not significant within the the boundries of the .05 level. These findings are graphically represented in Figure 2.

Table I

MEAN TORQUE VALUES AND MEAN EFFECTS CORRECTED FOR THE COVARIATE FOR KNEE EXTENSION (N-m)

Group	Pre-test Mean	Post-test Mean	Corrected Mean
Hydra-Gym	113.90	149.99	65.53
Nautilus	128.30	174.83	79.69
Control	138.12	132.41	29.98

FIGURE 1

PROFILE OF MEANS FOR KNEE EXTENSION

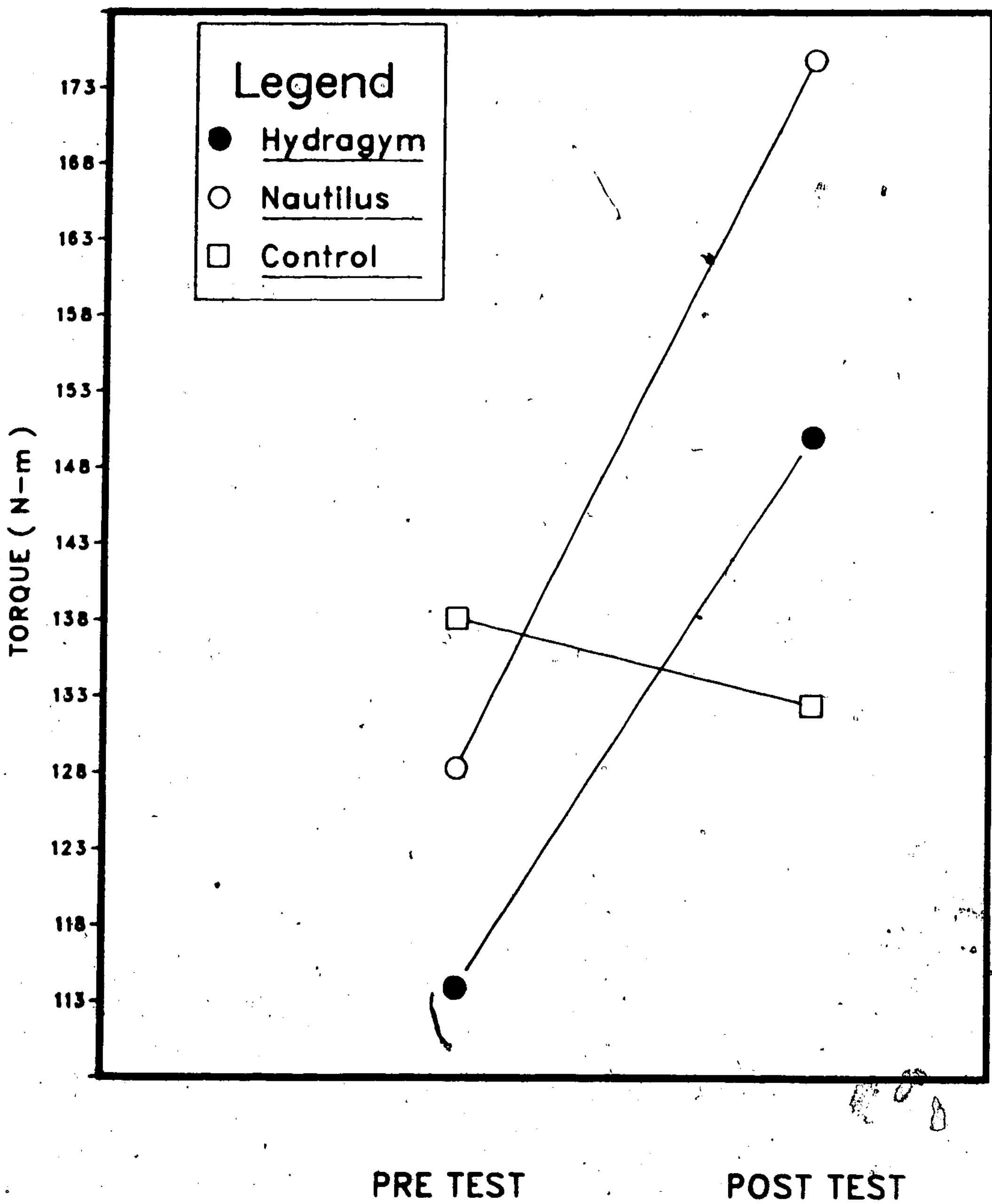
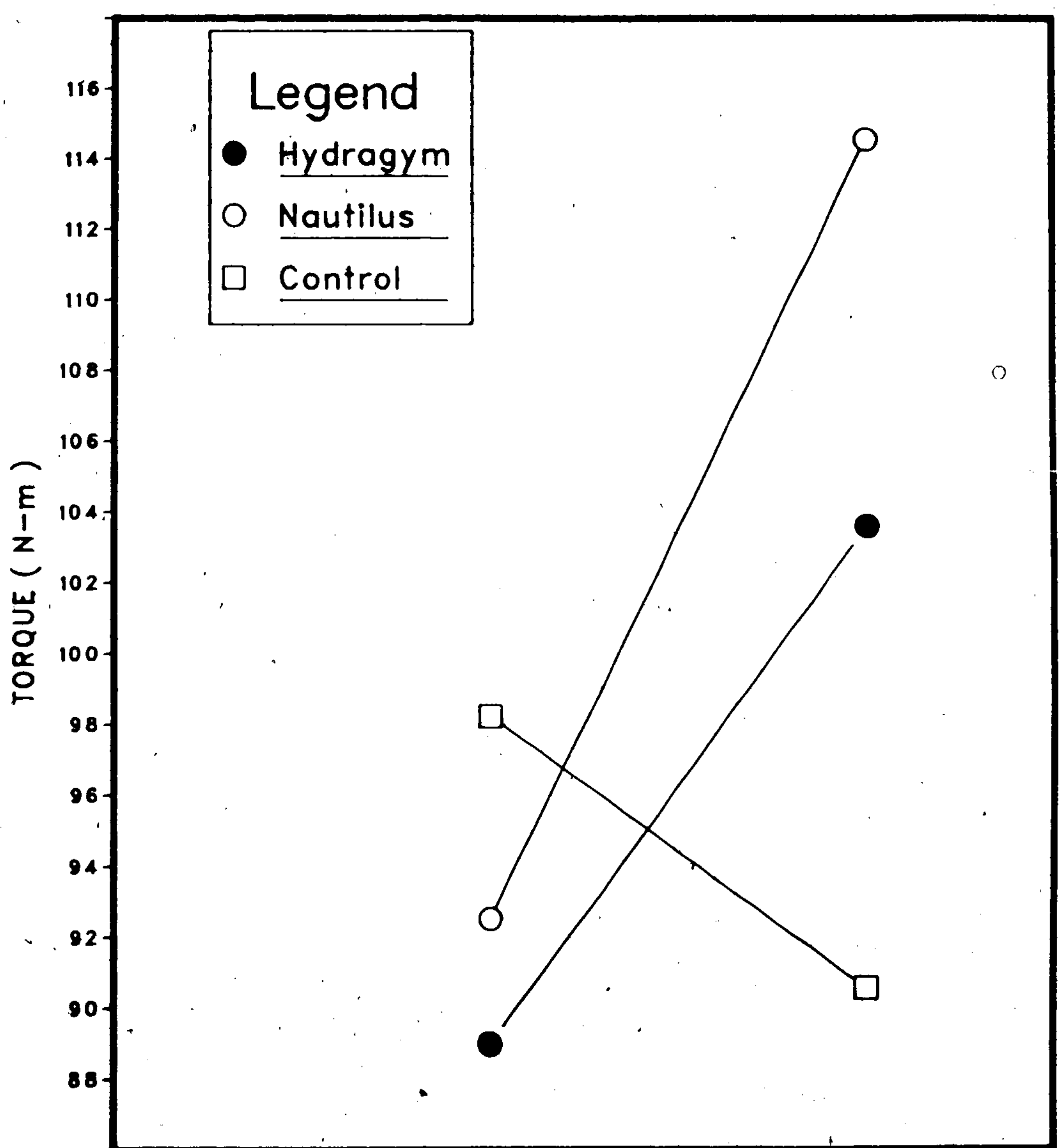


FIGURE 2

PROFILE OF MEANS FOR KNEE FLEXION



PRE TEST POST TEST

Table II

MEAN TORQUE VALUES AND MEAN EFFECTS CORRECTED FOR THE COVARIATE FOR KNEE FLEXION (N-m)

Group	Pre-test Mean	Post-test Mean	Corrected Mean
Hydra-Gym	88.97	103.58	53.28
Nautilus	92.52	114.54	62.24
Control	98.23	90.57	35.05

A summary of the results of the analysis of covariance for knee extension is illustrated in Table III. The overall treatment effects were significant at the .001 level of significance. The overall mean treatment effects corrected for the covariate and the individual contrasts for the corrected means for knee extension are presented in Table IV. There was no statistical significant difference between treatment groups at the .05 level of significance. There was however, a statistical significant difference between the control group and treatment groups at the .001 level of significance.

Table III

SUMMARY OF ANALYSIS OF COVARIANCE FOR KNEE EXTENSION TORQUE VALUES

Source of Variation	Sums of Squares	df	Mean Squares	F Ratio	p
SS Model	946142.81				
SS due to mean	923058.00				
SS due to treatment and covariate	23084.81	3	7694.94	14.02	<.001*
SS due to covariate	6418.19	1	6418.19	11.70	<.01*
SS due to treatment	16666.62	2	8333.31	15.19	<.001*
SS error	19752.13	36	548.67		

Table IV

INDIVIDUAL AND OVERALL TREATMENT EFFECTS CORRECTED FOR THE COVARIATE FOR THE ANALYSIS OF COVARIANCE IN KNEE EXTENSION

Source	df	F Ratio	p
Overall Treatment Effects	(2,36)	15.19	<.001*
Individual Contrasts			
H vs N	(1,36)	2.22	>.145
N vs C	(1,36)	29.39	<.001*
H vs C	(1,36)	12.94	<.001*

H=Hydra-Gym N=Nautilus C=Control

*significant

A summary of the results of the analysis of covariance for knee flexion is illustrated in Table V. The overall treatment effects were significant at the .001 level of significance. The overall mean treatment effects corrected for the covariate and the individual contrasts for the corrected means for knee flexion are presented in Table VI. There was a statistical significant difference between the treatment groups at the .05 level of significance and between the control group and treatment groups at the .001 level of significance.

Table V

SUMMARY OF ANALYSIS OF COVARIANCE FOR KNEE FLEXION TORQUE VALUES

Source of Variation	Sums of Squares	df	Mean Squares	F Ratio	p
SS model	427554.25				
SS due to mean	420966.75				
SS due to treatment and covariate	6587.50	3	2195.83	20.07	<.001*
SS due to covariate	1568.66	1	1568.66	14.34	<.01*
SS due to treatment	5018.84	2	2509.42	22.94	<.001*
SS error	3937.94	36	109.39		

*significant

Table VI

INDIVIDUAL AND OVERALL TREATMENT EFFECTS CORRECTED FOR THE COVARIATE FOR THE ANALYSIS OF COVARIANCE IN KNEE FLEXION

Source	df	F Ratio	p
Overall Treatment Effect	(2,36)	22.94	<.001*
Individual Contrasts			
H vs N	(1,36)	4.72	<.036*
N vs C	(1,36)	44.42	<.001*
H vs C	(1,36)	19.19	<.001*

H=Hydra-Gym N=Nautilus C=Control

*significant

Discussion

The results of the present study indicates that after a six week training period a significant increase in strength in the quadriceps and hamstrings was observed at a velocity of 0.524 r/s (30 deg/s) (p<.001). These findings are consistent with those of other researchers utilizing variable and semi-accommodating resistance training equipment (4, 22, 25, 26, 41, 42, 43). The present data suggests that significant muscular adaptations occurred, thus increasing the ability to generate strength during short term work. It is plausible to suggest that any increases in muscular strength is related to muscular hypertrophy and/or due to muscle innervation. The strength of a muscular contraction is dependent on the number of motor nerve fibres which are activated in the muscles during exercise, the rate in which the impulses are discharged, and/or the amount of contractile protein developed and stored by the muscle (28, 39). With untrained muscles, initial strength gains are essentially due to the activation of previously dormant fibres. As the training program continues, strength gains are most likely due to a combination of physiological changes occurring in the muscles.

The pooled regression analysis of covariance on peak torque scores demonstrated that the Hydra-Gym training machine has no advantage over the Nautilus training machine or visa versa in quadriceps strengthening. Perhaps the six week experimental period was not long enough to elicit a significant effect. However, the Nautilus training machine was significantly superior ($p<.05$) to the Hydragym training machine for increasing strength in the hamstring muscle group. This may be due to the fact that the subjects in the Nautilus training group exercised the quadriceps and hamstrings separately on two different machines. The subjects in the Hydra-Gym training group had to exercise both muscle groups at the same time, thus, more concentration may have occurred in the knee extension phase rather than concentrating on both the knee extension and knee flexion movements at the same time. Further, the quadriceps, due to their advantageous insertion to the skeletal system, are a stronger muscle group than the hamstrings. The skeletal advantage and the size of the muscles in the quadriceps provide for a greater resistance to be generated in the knee extension phase, than in the knee flexion phase. This may have been the cause for emphasizing the knee extension phase, thus reducing the effects of the knee flexion phase of the exercise. Another possible explanation for the superiority of the Nautilus training group over the Hydra-Gym training group, for hamstring strengthening, is the fact that a few of the subjects in the Hydra-Gym training group experienced bruising on the back of the knees. This would hinder the performance of the individual when they tried to exert maximal force in the flexion phase of the exercise.

The results also demonstrated that the control group generated less torque in the post-test than in the pre-test, in the hamstrings and quadriceps, over the six week experimental period. This decrease was not significant at the .05 level. This may have been due to the subjects motivation level during the testing sessions. The subjects enthusiasm upon entering the study, may have been the cause for higher peak torque scores on the pre-test. Once the subjects were placed into the control group, their motivation levels may have dropped, (ie. less enthusiastic about participating in the study), thus producing lower torque scores on the post-test measurement, (in comparison to the pre-test scores).

One of the major problems in comparing the effectiveness of two different types of resistance machines is the difficulty in equating the work accomplished in the training programs. In the present study, the manufacturers general guidelines were taken into consideration when equating the work loads for the two training programs. The Nautilus training group performed one set of 8 to 12 repetitions on two machines. One repetition took 5 seconds to perform, which resulted in 80 to 144 seconds of work, per training session. The Hydra-Gym training group performed four sets of repetitions on one machine that simultaneously exercised the quadricep and hamstring muscle groups. One set consisted of 20 seconds of work. The total time of work for the Hydra-Gym group was 80 seconds, per training session. In comparing the workloads for the Hydra-Gym and Nautilus training group, the Nautilus training group performed more work (in terms of time) than the Hydra-Gym training group. The longer work period for the Nautilus training group may have been advantageous in altering the neural activity that accompanies strength gains. Simply, a longer training stimulus would result in a greater response to muscle-nerve innervation and motor unit activity. This may warrant the results of the Nautilus training machine being significantly superior ($p<.05$) to the Hydra-Gym training machine in affecting changes in muscular strength in the hamstring muscle group.

Further research is needed regarding the intensity and duration of training before workloads may be precisely equated with different types of resistance machines.

CHAPTER 5

SUMMARY AND CONCLUSIONS

Purpose

The purpose of the present study was to compare the Nautilus leg flexion and leg extension variable resistance machines, with the Hydra-Gym unilateral quadricep/hamstring omnikinetic machine, in their ability to affect changes in peak muscle torque, using the training protocols recommended by the manufacturers of the equipment.

Subjects

The sample consisted of forty volunteer sedentary women with no significant history of lower limb pathology. The subjects were randomly selected into three groups, followed by random assignment of treatments to groups.

Procedures

The subjects were tested on a Cybex II isokinetic dynamometer prior to the start of the program and immediately following the completion of the training program. Peak muscle torque of the quadriceps and hamstrings was measured at an angular velocity of 0.524 r/s (30 deg/s).

The subjects trained on either the Hydra-Gym unilateral quadricep/hamstring machine or on the Nautilus leg extension and leg flexion machines, three times a week for a period of six weeks. The control group did not exercise for the duration of the six week program.

A pooled regression analysis of covariance was applied to the data to determine whether there was a statistical significant difference between treatment groups.

Results

An examination of the data indicated that the training groups produced significant changes in muscular strength in the quadriceps and hamstrings ($p<.001$).

The Nautilus equipment was superior to the Hydra-Gym equipment in affecting changes in strength in the hamstring muscle group ($p<.05$).

Further, there was no significant difference (at the .05 level) in the type of training machine used for strengthening the quadricep muscle group.

Conclusions

From the testing protocol, training protocol, and experimental method used in the present study, the following conclusions are warranted:

1. Muscular strength can be significantly increased in the quadriceps and hamstrings on a training program utilizing variable and semi-accommodating resistance training.

2. Variable resistance training is superior in increasing strength in the hamstrings as compared to semi-accommodating resistance training.
3. There is no significant difference between variable and semi-accommodating resistance training programs for increasing muscular strength in the quadriceps.

Recommendations

The results of the present study demonstrated that variable and semi-accommodating resistance strength training showed improvements in muscle torque output. The following recommendations are listed in order to encourage further research in the area of resistance training.

1. This research was conducted to ascertain the effectiveness of the Nautilus variable resistance machines and the Hydra-Gym semi-accommodating resistance machine, in their ability to affect changes in muscular strength in the quadriceps and hamstrings. This study could be repeated by utilizing various Nautilus and Hydra-Gym exercise machines, so that several different groups of muscles may be exercised, as opposed to limiting the exercises to the quadricep and hamstring muscle groups. As a result of exercising various muscle groups on different resistance exercise machines, comparative research may be conducted regarding changes in muscular strength and power, anaerobic and aerobic work capacity, and, body composition.

2. Further research is needed involving the intensity and duration of exercise, so that the work accomplished in training programs utilizing different resistance machines, may be precisely equated.
3. Future investigation could be conducted on specific groups of women athletes to determine the effectiveness of variable and semi-accommodating resistance training.

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APPENDICES

APPENDIX A

RAW DATA

RAW DATA FOR HYDRA-GYM TRAINING GROUP (N-m)

Subject	Age	Knee Flexion Pre	Knee Flexion Post	Knee Extension Pre	Knee Extension Post
1	19	92.2	101.7	122.0	135.6
2	22	81.4	97.6	96.3	146.5
3	26	65.1	77.3	108.5	113.9
4	21	97.6	105.8	122.0	162.7
5	21	97.6	116.6	122.0	143.7
6	21	75.9	97.6	105.8	154.6
7	22	122.0	134.2	130.2	215.6
8	20	97.6	113.9	105.8	196.6
9	23	65.1	88.1	130.2	150.5
10	22	105.8	111.2	126.1	138.3
11	21	65.1	93.6	97.6	126.1
12	29	97.6	105.8	104.4	138.3
13	20	93.6	103.1	109.8	127.5
	MEAN	89.0	103.6	113.9	150.0

Note: N-m of torque may be converted to ft-lbs of torque by dividing by 1.356.

RAW DATA FOR NAUTILUS TRAINING GROUP (N-m)

Subject	Age	Knee Flexion Pre	Knee Flexion Post	Knee Extension Pre	Knee Extension Post
1	24	97.6	105.8	122.0	146.5
2	19	93.6	130.2	138.3	215.6
3	20	90.9	130.2	94.9	158.7
4	24	89.5	97.6	112.6	135.6
5	21	85.4	103.1	126.1	146.5
6	20	97.6	130.2	130.2	219.7
7	22	88.1	101.7	126.1	158.7
8	20	99.0	135.6	184.4	211.5
9	30	92.2	97.6	126.1	154.6
10	19	92.2	103.1	149.2	162.7
11	28	101.7	130.2	113.9	157.3
12	28	101.7	126.1	127.5	215.6
13	21	73.2	97.6	116.6	189.8
	MEAN	92.5	114.5	128.3	174.8

Note: N-m of torque may be converted to ft-lbs of torque by dividing by 1.356.

RAW DATA FOR CONTROL GROUP (N-m)

		Knee Flexion		Knee Extension	
Subject	Age	Pre	Post	Pre	Post
1	25	81.4	93.6	120.7	105.8
2	25	93.6	96.3	105.8	97.6
3	27	62.4	73.2	122.0	130.2
4	21	101.7	90.9	179.0	146.5
5	20	92.2	89.5	109.8	113.9
6	18	97.6	97.6	103.1	122.0
7	20	130.2	118.0	207.5	208.8
8	19	101.7	81.4	126.1	122.0
9	21	105.8	89.5	153.2	124.8
10	23	101.7	89.5	179.0	154.6
11	23	130.2	81.4	138.3	150.5
12	21	93.6	89.5	124.8	118.0
13	20	101.7	88.1	142.4	130.2
14	22	81.4	89.5	122.0	128.8
	MEAN	98.2	90.6	138.1	132.4

Note: N-m of torque may be converted to ft-lbs of torque by dividing by 1.356.

APPENDIX B

CYBEX II TORQUE CHANNEL CALIBRATION

CYBEX II TORQUE CHANNEL CALIBRATION

Recorder Scale Selector: 180 ft-lbs

Lever Arm: 31 inches*

Weight: 32.5 lbs

Graph Recording Peak: 5 major divisions (90 ft-lbs)

*Measure distance from centre of dynamometer input shaft to center of calibration T-bar cross tube (lever arm length).

Calibration Procedure:

1. Turn power on and allow for five minutes warm up.
2. Set torque channel scale to 180 ft-lbs.
3. With speed selector ON at 30 deg/s or 0.524 rad/s, and the recorder ON, but no torque applied to the lever arm:
   a. Select #3 position on Damping control.
   b. Select slow chart speed (5 mm/s).
   c. Align stylus with baseline of chart grid paper using "Zero Adjust" control on recorder.
   d. Switch foot-pound scale to 30. Check to see baseline does not shift when range scale is changed from 180 to 30. Baseline shift can be corrected by adjusting with a small screwdriver, the potentiometer on the top right side of the recorder (marked zero null).
4. Attach balanced weighed disc weights (32.5 lbs ±1) to the T-bar.

5. Dynamic calibration is performed by manually lifting the weighted T-bar to the vertical position and allow gravity to swing it down until the weights contact the floor. As the weighted arm passes the horizontal, the graph recording will show this value as a maximum point on the curve (5 major divisions on the graph paper). If this point is above or below the correct torque value, adjust the potentiometer for the 180 ft-lb scale through the holes on the top right side of the recorder, using the small screwdriver. Turning the potentiometer clockwise increases the torque reading, and counter clockwise will decrease it.

Torque measurement repeatability:
Test-retest reliability = 0.995 (33).

APPENDIX C

CYBEX II POSITION ANGLE CALIBRATION

Cybex Position Angle Calibration

There are two scale settings (150 and 300 degrees). Since the joint pattern of this study did not exceed 150 degrees, this was the scale selected.

Procedure:

1. Turn on power.
2. Select degree scale (150 degrees).
3. Select chart speed at 5 mm/s.
4. Set input to CCW (counter clockwise).
5. While depressing the zero button, use position angle ZERO ADJUST Knob to adjust stylus to zero baseline. Release Zero Test Button.
6. Adjust position angle channel stylus to zero baseline by turning the goniometer dial on the dynamometer, clockwise.
7. Recheck steps #5 and #6 until the stylus does not deviate from zero baseline when the Zero Button is pressed or released.
8. Using the white line under the goniometer dial as an index mark, rotate the dial clockwise 150 degrees. If the stylus traces a line on the top line of the graph, no adjustment is necessary. If the stylus lies above or below the top line, repeat steps #5 through #8 to verify the reading. If no adjustment is necessary, proceed to step #9.

9. Locate the "Deg. Cal." screw on the recorder panel. Using a 7/16 inch wrench, slightly loosen the locking nut that secures the screw. With a standard slot screwdriver, turn the screw to move the stylus line precisely to the top of the line on the Position Angle chart. Using the screwdriver to hold this position, snug down the locking nut. Re-check calibration by repeating steps #5 through #8.

APPENDIX D

CYBEX II SPEED SELECTOR CALIBRATION

Cybex Speed Selector Calibration

Procedure:

1. Turn on power and allow for 5 minutes warm up.
2. Attach adjustable arm with push-button, locking collar with thumb-screw and handgrip.
3. Adjust speed to 180 deg/s (3.144 rad/s).
4. Using a stopwatch, determine the time necessary to complete fifteen revolutions in either direction. Be sure to keep the dynamometer torque gauge needle above zero for the entire timing duration. Complete at least one full revolution before starting timer.
5. Calculate actual R.P.M.: Divide 900 by the number of seconds it takes to complete 15 revolutions. The results is the actual R.P.M. of the input shaft.
6. If the R.P.M. is 30 ($\pm$.3) the tachometer is reading correctly and requires no adjustment. If the actual R.P.M. is less than 29.7 or greater than 30.3, repeat the timing and calibration procedure to check for human error.

Test-retest reliability = .985 (33).

APPENDIX E

EXAMPLE OF CYBEX II LEG EXTENSION/FLEXION PRINTOUT

EXAMPLE OF CYBEX II LEG EXTENSION/FLEXION PRINTOUT

(30 deg/s)

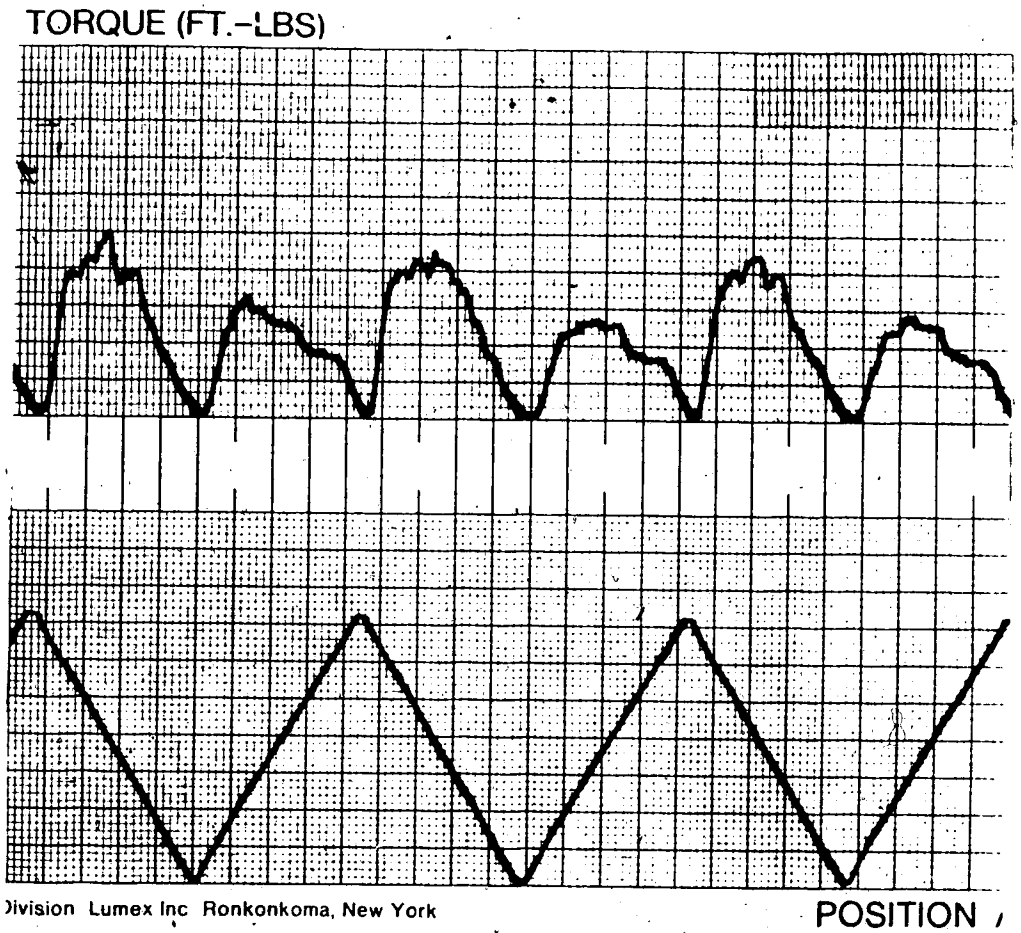
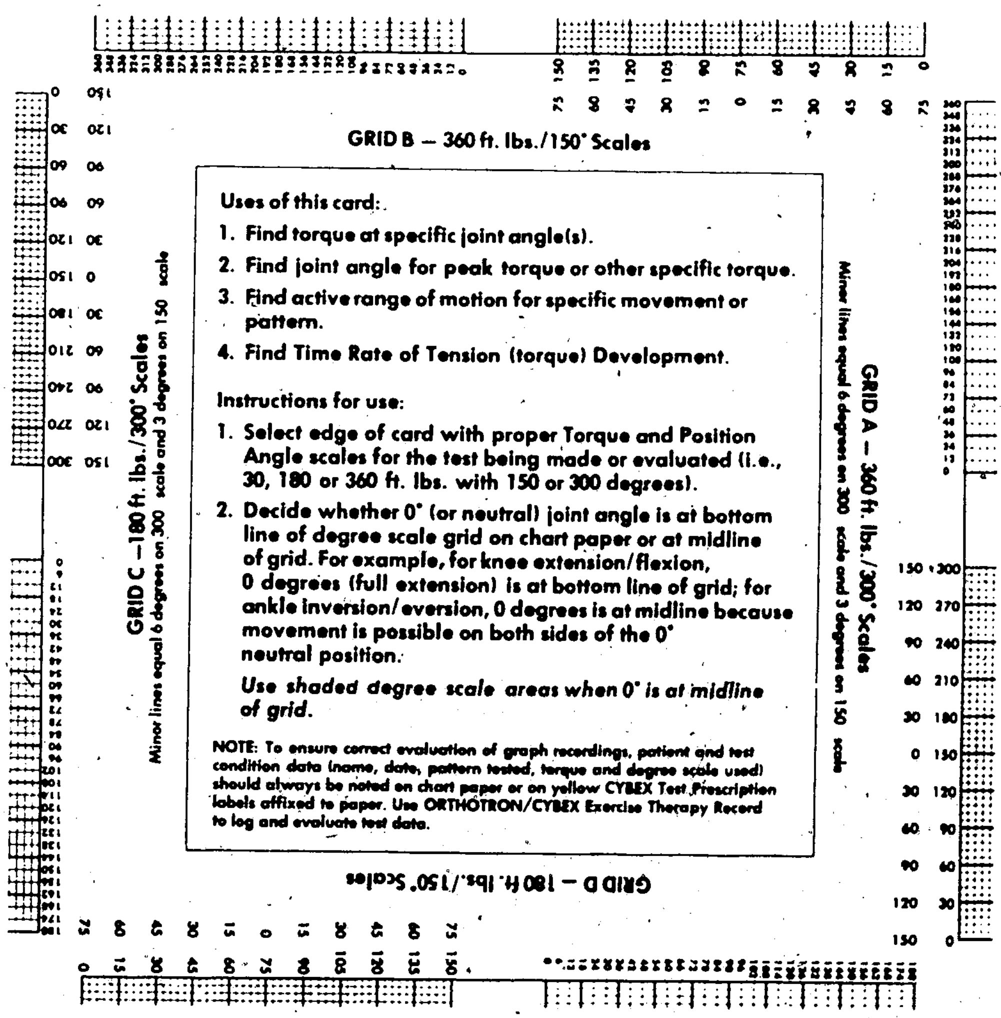


Chart speed = 5 mm/s
Torque scale = 180 ft-lbs
Angle scale = 150 degrees

APPENDIX F

CYBEX II CHART DATA CARD

CYBEX II CHART DATA CARD



APPENDIX G

CONSENT FORM

CONSENT FORM

The University of Alberta

Department of Physical Education

INFORMED CONSENT FORM FOR THE FOLLOWING STUDY:

COMPARISON OF THE EFFECTIVENESS
OF VARIABLE AND SEMI-ACCOMMODATING RESISTANCE TRAINING
IN QUADRICEP AND HAMSTRING STRENGTHENING
IN WOMEN

SUBJECT CONSENT:

I, ______________________ do herby agree to participate as a subject in the study entitled, "Comparison of the Effectiveness of Variable and Semi-Accommodating Resistance Training in Quadricep and Hamstring Strengthening in Women", conducted by Angela Kochan. I have been fully informed of all risks and stresses that are associated with this study. I do not suffer, nor have I ever suffered, any leg injury, medical condition, disease, or disability, which may prevent me from participating in this study. I also understand that I may not participate in any athletic activities during the training program, and that I may withdraw from this study at any time.

SIGNED ______________________

DATE ______________________

ADDRESS ______________________

PHONE ______________________

APPENDIX H

EXERCISE TESTING DATA RECORD SHEET

EXERCISE TESTING DATA RECORD SHEET

NAME: ______________________________

GROUP: ______________________________

AGE: ______________________________

VELOCITY: 30 deg/s (0.524 rad/s)

#REPS FOR PEAK TORQUE: 5

CUSHIONS: ______________________________

LEVER ARM LENGTH: ______________________________

DYNAMOMETER LENGTH: ______________________________

	PRE-TEST		POST-TEST	
DATE				
WEIGHT (lbs)				
	EXTENSION	FLEXION	EXTENSION	FLEXION
PEAK TORQUE (N-m)				

RIGHT LEG

LEFT LEG

APPENDIX I

EXERCISE TRAINING DATA RECORD SHEET

NAUTILUS TRAINING PROGRAM RECORD SHEET

	LEG FLEXION MACHINE		LEG EXTENSION MACHINE	
DATE	WEIGHT (lbs)	# reps	WEIGHT (lbs)	# reps

HYDRA-GYM TRAINING PROGRAM RECORD SHEET

\# OF REPETITIONS IN 20 SECONDS

DATE	DIAL SETTING	SET 1	SET 2	SET 3	SET 4

APPENDIX J

EQUIPMENT LIST

EQUIPMENT LIST

1.) CYBEX II ISOKINETIC DYNAMOMETER, SPEED SELECTOR, DUAL CHANNEL RECORDER, AND DATA REDUCTION COMPUTER.

Manufacturer
Cybex Division of Lumex Inc.
2100 Smithtown Ave.
Ronkonkoma, New York
11779

2.) NAUTILUS LEG FLEXION AND LEG EXTENSION MACHINE

Manufacturer
Nautilus Sports/Medical Industries
P.O. Box 1783
Deland, Florida
32720

3.) HYDRA-GYM UNI-LATERAL LEG FLEXION/EXTENSION MACHINE

Manufacturer
Hydra-Fitness Industries
Division of Hydra-Gym
P.O. Box 599
Belton, Texas
76513