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The effects of isotonic and isokinetic training upon strength of knee extension

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The Effects of Isotonic and Isokinetic Training Upon Strength of Knee Extension

By

Merle V. Baker

An Abstract

of a thesis submitted in partial fulfillment

of the requirements for the degree of

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Thesis Advisor: Dr. G. A. Sforzo

ABSTRACT

This study investigated isotonic and isokinetic training effects upon strength at specific joint angles during knee extension. The subjects were 12 State University of New York College at Cortland students (7 females, 5 males). The study consisted of one group that exercised on the Cybex II isokinetic dynamometer and another that used the Nautilus variable-resistance isotonic leg extension machine. Each group was randomly assigned 6 subjects, who trained both legs for a 7-week period. The Cybex group trained at 60°/s, executing three sets of six repetitions, three times per week. The Nautilus group used a modified Delorme-Watkins training protocol, also performing three sets of six repetitions, three times per week. Both legs of the subjects were pretested and posttested using maximal isometric contractions performed on the Cybex II at 85°, 95°, 150°, 160°, and 170° of knee extension. A four-way ANOVA (Group by Sex by Leg by Time) run at each joint angle identified that significant ($p < .05$) strength improvement had taken place over the training period. Subsequently, an ANCOVA with pretraining strength as the covariate identified that there were no statistically significant ($p < .05$) differences between the groups in strength acquisition at specific joint angles. Although some previous evidence suggested that the Cybex II isokinetic dynamometer may not provide optimal resistance during its acceleration and deceleration phases, the results of the present study indicated that it conditioned the extreme points in the ROM during knee extension as effectively as Nautilus training. Therefore, it is concluded that the Cybex

provides an adequate challenge to knee extension during the acceleration and deceleration phases and allows strength enhancement.

The Effects of Isotonic and Isokinetic Training Upon Strength of Knee Extension

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A Thesis Presented to the Faculty of
the Division of Health, Physical
Education, and Recreation
Ithaca College

In Partial Fulfillment of the
Requirements for the Degree
Master of Science

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by

Merle V. Baker

December 1988

Ithaca College

Division of Health, Physical Education, and Recreation

Ithaca, New York

CERTIFICATE OF APPROVAL

MASTER OF SCIENCE THESIS

This is to certify that the Master of Science Thesis of

Merle V. Baker

submitted in partial fulfillment of the requirements for the degree of Master of Science in the Division of Health, Physical Education, and Recreation at Ithaca College has been approved.

Thesis Advisor:

Committee Member:

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Dean of Graduate Studies:

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DEDICATION

This thesis is dedicated to my wife, Laura. Your love, support, and patience have helped me to persevere with my work, as well as enjoy our time together.

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Chapter 1

INTRODUCTION

The knee is the most commonly injured joint in all of athletics (O'Donoghue, 1970; Ritchey, 1963) and is most frequently the site of disabling injuries in sports (Klein & Allman, 1969; Ryan, Slocum, Larson, James, Standifer, & Durkey, 1975). Because of this, maintenance and efficient rehabilitation of the knee joint musculature for the athlete are of major concern. It is well accepted that strengthening the surrounding muscles is crucial for proper rehabilitation of knee injuries. Many authorities emphasize the importance of leg extension exercises in knee rehabilitation programs (Allman, 1974; Nicholas, 1973; O'Donoghue, 1970; Ryan, 1962). This study examines the strengthening of knee extensors utilizing the Cybex II isokinetic dynamometer and the Nautilus leg extension machine with progressive resistive exercise. Both the Nautilus (variable resistance isotonic) and the Cybex II (isokinetic) machines claim to provide resistance to the working muscle group through the full range of motion. Several studies have indicated this may not be entirely true, especially during the acceleration and deceleration phases with the Cybex II (Davies, 1984; Sapega, Nicholas, Sokolow, & Saraniti, 1982; Thistle, Hislop, Moffroid, & Lowman, 1967; Winter, Wells, & Orr, 1981). It is conceivable that strengthening and rehabilitation are not taking place optimally at certain joint angles using this type of training. The purpose of this study was to compare these training devices (i.e., Cybex II and Nautilus) in regard to strength improvements at specific joint angles during knee extension following 7 weeks of training.

Scope of Problem

A 7-week physical training program was established for male and female college students to compare isotonic and isokinetic training effects upon strength at specific joint angles during knee extension. Subjects (N = 12) were randomly assigned to two training groups: an isotonic training group utilizing a Nautilus leg extension machine and an isokinetic training group utilizing a Cybex II dynamometer. All subjects were pretested bilaterally on the Cybex II to determine a maximal isometric contraction at five joint angles of extension (85^{o}, 95^{o}, 150^{o},160^{o}, 170^{o}). Both training groups exercised three times per week, performing three sets of six repetitions with each leg independently. Following 7 weeks of training, the subjects performed a posttest on a Cybex II dynamometer to determine if a training effect had occurred and if any differences in strength acquisition existed between the groups.

Statement of Problem

The study was undertaken to determine if subjects who trained isotonically and those who trained isokinetically had equivalent strength improvements at predetermined angles of knee extension.

Null Hypothesis

There will be no difference in strength improvements at specified joint angles between the isotonic and isokinetic training groups.

Assumptions of Study

The following were assumptions of this study:

1. Subjects in both training groups were equally motivated, therefore both groups put forth relatively equal work.

2. If strength increases occurred following a 7-week training program, the increases would be due to a training effect.

3. An isometric contraction performed on a Cybex II is an accurate measure of strength for both training groups, and posttests would not reflect a learning effort in the Cybex-trained.

4. All aspects of the exercise for both the isokinetic and isotonic groups were equated numerically providing similar work intensities between the modes.

Definition of Terms

The following terms were operationally defined for the purpose of this study:

1. Isometric Contraction: The contraction of a muscle at a constant angle without noticeable shortening.

2. Isotonic Contraction: The contraction of a muscle throughout a range of motion accompanied by a change in muscle length and tension generated.

3. Isokinetic Contraction: The contraction of a muscle throughout a range of motion performed at a mechanically predetermined and controlled acceleration.

4. Muscular Strength: The maximum amount of force exerted by a muscle group in one maximum isometric effort as measured by peak torque on a Cybex II dynamometer.

5. Specific Joint Angle: One of five specified points in the extension of the knee used as reference positions in this study and designated as such by specific units of degrees. Complete extension can be defined as 180^0 of

extension, terminal extension, anatomical zero, or 0° of flexion. For the purposes of this study, the degrees of joint angle will be referred to in degrees of extension. Each subject's starting point of reference was full flexion of the knee joint, with his/her heel in contact with the base pad of the Cybex II testing table (approximately 85° of extension). A maximal isometric contraction was first taken in the full flexion position. Then joint angle readings were assessed at an additional 10° and 65° into extension (approximately 95° and 150° of extension). The final two readings for each limb were taken at 160° and 170° of extension, approximately 10° and 20° shy of terminal extension. Each joint angle position was relative to each subject's position of full flexion and terminal extension (attempting to avoid hyperextension of the knee joint).

6. <u>Acceleration Phase</u>: The initiation of leg extension, during which the Cybex II offers little to no resistance because the limb has not reached the preset speed of the isokinetic machine.

7. <u>Deceleration Phase</u>: The completion of leg extension, during which the limb speed tends to drop below the preset speed of the Cybex II as terminal extension is reached. Because limb speed must equal the preset speed of the isokinetic device to encounter resistance, little to no resistance is offered.

Delimitations of Study

The delimitations of the study were as follows:

1. The subjects were 7 females and 5 males from the State University of New York (SUNY) College at Cortland.

2. Training extended over a 7-week period with three training sessions per week.

3. Subjects trained on either a Cybex II isokinetic dynamometer (Division of Lumex, Inc., Ronkonkoma, NY) or a Nautilus leg extension machine (Nautilus Sports Medicine Industries, Deland, FL).

4. Five specific joint angles (85^0, 95^0, 150^0, 160^0, and 170^0) were isometrically pretested and posttested bilaterally for each subject.

5. Subjects in both groups trained three times weekly, bilaterally performing three sets of six repetitions of leg extension exercises. A rest interval of 2 min was employed between sets.

<u>Limitations of Study</u>

The following limitations existed for this study:

1. The amount of outside physical activity in which the subjects participated during the study was not completely controlled, although an attempt was made to limit outside activities and exercise.

2. The relatively small sample size limits the power of statistical analysis.

3. The results of the study may only apply when the Cybex II, without the optional ramping device, and the Nautilus leg extension device are utilized to strengthen the knee extensors.

4. The results of the study may only apply when the same joint angles are tested (85^0, 95^0, 150^0, 160^0, and 170^0).

5. The results of the study only apply when a maximal isometric contraction is employed to measure strength.

6. Although sets and repetitions were identical, work provided by each repetition may have been substantially different because no specific precautions were taken to equate the groups' work efforts.

Chapter 2

REVIEW OF RELATED LITERATURE

This chapter reviews literature related to theoretical questions raised concerning the effectiveness of isokinetic strength training devices as related to extremes in the range of motion (ROM) of knee extension, strengthening at specific joint angles, and the use of maximal isometric testing at specific joint angles as an evaluative tool for dynamically acquired strength. In addition, comparative isotonic and isokinetic studies and literature concerning the methodologies used in strength training research will also be discussed.

Comparative Studies: Isokinetics Versus Isotonics

Since the introduction of the isokinetic dynamometer, investigators have searched to find a clear answer to which mode of exercise is more thorough, isokinetic or isotonic. Although an unequivocal conclusion has not been reached, consider the established advantages associated with isotonic and isokinetic exercise modes as presented below.

Advantages of Isotonics

Readily accepted advantages of isotonic exercise include (a) relative low cost, (b) availability, (c) motivation by increments of weight lifted, (d) the ease in which varying increments can be added or subtracted so as to comply with the progressive overload principle, (e) working through the ROM, (f) working at speeds greater than $0^{o}/s$, (g) working with both concentric and eccentric contractions, (h) ability to improve muscular endurance utilizing more than 10 to 15 repetitions, (i) improving the neurophysiological system, (j) affording objective documentation, (k) ease of manipulating components of the program to maintain workload (i.e., sets, repetitions, weight), and (l) performing relatively few repetitions for a desired increase in strength (approximately 1 to 10 repetitions) (Davies, 1984).

Advantages of Isokinetics

The isokinetic mode of exercise also possesses many advantages for the individual who is concerned with strength training and performance. These advantages include (a) the presence of accommodating resistance, which enables the individual to receive maximal dynamic overload throughout the ROM, (b) the availability of maximal loading with varying limb speed, (c) a good safety factor, because the machine does not require the loading of weight on, above, or under a limb, (d) minimal postexercise soreness due to the absence of eccentric contractions, (e) reliability, validity, and reproducibility of the torque readings measured by the dynamometer (Johnson & Seigel, 1978; Moffroid, Whipple, Hofkosh, Lowman, & Thistle, 1969), (f) hard copy graphic recording output providing an objective report, (g) the allowance of exercise at speeds closer to joint speeds associated with athletic competition (specificity of exercise), (h) the decreasing of reciprocal innervation time of agonist/antagonist contractions, (i) the machine's accommodation to pain and fatigue, (j) the stimulation of joint nourishment via the synovial capsule, (k) the decrease of compressive joint forces at high speeds, (l) the provision of feedback to the individual via the dynamometer readout, and (m) the availability of objective supervision of submaximal and maximal programs and progression (Davies, 1984).

Quite a few studies have compared isokinetic and isotonic exercise with no conclusive results. These investigations vary greatly in exercise protocol (i.e., sets, repetitions, rest intervals, duration). In addition, not all use strength as their final posttest indicator. Several of the investigators determined their results based on motor performance. These incongruities aside, the literature comparing isotonic and isokinetic exercise is examined.

Isokinetics Found Superior to Isotonics

In an electromyographic study with a group of 13 college-aged women, Rosentswieg and Hinson (1972) tested for maximal isokinetic, isotonic, and isometric contractions of the biceps brachii. The integrated electromyographic data revealed that the isokinetic contractions elicited significantly greater muscle action potentials than the isometric and isotonic contractions.

In an electromyographic followup to their 1972 study, Hinson and Rosentswieg (1973) studied 52 college women, whom they tested for maximal isokinetic, isotonic, and isometric contractions of the elbow flexors and knee extensors. They concluded that isokinetic strength training was superior to isotonic and isometric training methods in eliciting muscle action potential. They stated isokinetic work would be the favored mode of exercise on the basis that it produced a greater action potential for a greater number of subjects. In addition, the investigation also revealed that there is a degree of specificity associated not only with the type of contraction, but also with the muscle being contracted.

In 1975, Pipes and Wilmore utilized 36 male volunteers randomly distributed into four groups that exercised isotonically, isokinetically at a slow speed, isokinetically at a fast speed, and a control. Each group trained three times per week for a duration of 8 weeks. The reported results showed clear superiority of the isokinetic procedures over the isotonic and control groups relative to strength, anthropometric measures, and motor tasks. Similar findings of isokinetic superiority were found in other investigations (Moffroid et al., 1969; Osternig, 1971). Hislop and Perrine (1967) also found isokinetic exercise to be significantly more productive, but with an additional comment in their conclusion that specificity of exercise was an important factor in isokinetic's favor. The capability of the Cybex II to exercise the limb at, or near, the velocities and ranges of motion normally associated with athletic performances is an important consideration when one is concerned with dynamic strengthening of a muscle group.

Isotonics Found Superior to Isokinetics

Several investigations have found isotonic exercise significantly more effective than isokinetic exercise (Campbell, 1974; Meadors, Crews, & Adeyanju, 1983). The study carried out by Meadors et al. incorporated 36 sedentary women, who were distributed into four equal groups of 9 subjects each. The four groups consisted of an isokinetic fast joint speed group, an isotonic group utilizing the Delorme progressive resistance protocol, an isotonic controlled-repetition group, and a control. The three exercising groups exercised three times per week for an 8-week duration. Findings indicated the two isotonic groups were superior to the isokinetic group with regard to muscular strength and endurance. This study was very similar in design to Moffroid et al. (1969) which found isokinetics to be superior.

Meadors et al. attempted to explain the conflicting results stating that in their investigation, an isotonic pretest/posttest evaluating device was used. The isotonic training group may have had an advantage due to familiarity with the testing device.

No Significant Differences Found Between Isokinetics and Isotonics

There are a large number of investigations which have shown no significant differences when comparatively examining isokinetic and isotonic exercise. One such study carried out by Shields, Beckwith, and Kurland (1985) examined 53 high school students from ages 13 to 18 in a leg strength study. The subjects were randomly assigned to to an isotonic exercise group, an isokinetic exercise group, and a control group. Their conclusion was that either type of training equipment could be used to increase strength and neither of the exercise groups was significantly different from the other. Several other studies found similar results (Delateur et al., 1972; Girardi, 1971; Hoffman, 1971).

One isokinetic/isotonic comparative study analyzed muscle biopsies and anaerobic power and found no significant differences between the isokinetic group and the isotonic (Etheridge & Thomas, 1982). Twenty-one untrained males aged 19-24 years participated in a 7-week, 3-days/week strength training study. Each subject was randomly assigned to two (one for each leg) of the five knee extension groups (slow isokinetic [90^{o}/s], fast isokinetic [180^{o}/s], isotonic, variable resistance, and control). Muscle biopsies were taken from the vastus lateralis. Single leg maximal aerobic power was measured using the Douglas bag technique. Results showed no improvements in isokinetic strength or single leg aerobic power. All groups improved in variable resistance 1 repetition maximum (RM), but only the isotonic and variable resistance groups improved in isotonic 1RM. There were no significant differences among groups in fiber area. The authors concluded that there are few, if any, differences among isotonic, variable resistance, slow isokinetic, and fast isokinetic strength training after 7 weeks of training. Three studies reviewed that utilized motor performance as a posttest indicator after the exercise training sessions (Hutinger, 1970 [swimming performance]; Tanner, 1971 [vertical jump]; Thurston, 1980 [motor performance]) also found no significant differences between the isotonic and isokinetic exercise groups.

The body of literature comparing isokinetic and isotonic exercise reviewed is far from conclusive. The conclusions span the spectrum of possible outcomes. One can also delve a little deeper into the isokinetic research and question some of theoretical claims revealed but not readily pursued.

Isokinetic Training in the Extreme Ranges of Motion

There are many differences between isokinetic and isotonic exercise, many of which were brought to light in the advantages section for each mode of exercise included at the beginning of this chapter. One of the inherent problems with the nature of the Cybex II isokinetic device is that it is a machine that must be accelerated to the preset speed before it will provide resistance to the exerciser. No torque can be recorded until the acceleration phase is complete. As the limb/lever arm mass catches up to the preset speed of the isokinetic dynamometer, an output is recorded and the resistance is encountered suddenly (Knapik, Wright, Mawdsley, & Braun, 1983; Sapega et al., 1982; Winter et al., 1981). This is often referred to by clinicians as "hitting the isokinetic wall." Because of the compliance of the machine, the leg actually exceeds the preset speed and then encounters the machine's resistance and is decelerated (Knapik et al., Sapega et al., Winter et al.). This is also referred to as "catching the machine." This indicates that the exerciser must be able to accelerate the limb being exercised fast enough to meet the predetermined exercise speed in order to be able to produce torque against it (Davies, 1984). If a person is exercising at approximately 200^{0}/s it will take approximately 20-25^{0} of the ROM to accelerate the limb to the preset speed where it will encounter resistance (Davies). Then the limb also must be decelerated at the end of the ROM so as to return the limb in flexion for a reciprocal concentric contraction. This would also leave a portion of the ROM near terminal extension of the knee where the preset speed is not being met (deceleration), as well as approximately the first 30^{0} that is neglected during acceleration. It would appear the exerciser is not receiving the full intensity of resistance in these suspect points in the ROM during knee extension.

Let us concentrate first on approximately the first 30^{0} of exercise that may be affected by the isokinetic catch-up phenomenon. Muscular response to different loading systems tends to be specific. In other words, a muscle which is overloaded in a partial ROM will increase strength significantly more in this range than in the neglected points (Winter et al., 1981). Because the limb has not met the speed of the machine and, in turn, has received no resistance until 15-30^{0} into the extension of the knee, will this neglected ROM not be strengthened as adequately? Overload is believed to be necessary to increase strength (Hellebrandt & Houts, 1956; Winter et al., 1981), and this portion of the ROM is not being overloaded. At higher isokinetic speeds it was found that peak torques were reached later in the ROM than with isotonic exercise (Knapik, Wright, et al., 1983; Winter et al., 1981). The delayed shift in the peak torque occurrence was attributed to (a) the time used by the limb to achieve the preset dynamometer velocity and (b) the time required to develop additional torque once the preset speed was achieved (Knapik, Wright, et al.). In fact, Gregor, Edgerton, Perrine, Campion, & DeBus (1979) suggested that isokinetic torque measurements during knee extension at angles within the first 30° are invalid because inadequate time is allowed to reach the maximal torque that is possible within that range. Ideally more work should be done to estimate the number of lag degrees affected as related to a specific training speed. The higher velocities possess the larger ROM lags because it takes the exercising limb greater time and distance to meet the higher preset speed of the machine.

The distal portion of the knee extension, or terminal extension, also tends to be an area of concern when training isokinetically. The limb must be decelerated at the end of the ROM so as to return the limb to flexion for a reciprocal concentric contraction. This would also leave a portion of the ROM near terminal extension of the knee where the preset speed is not being met (deceleration), thus there is not the full intensity of the accommodating resistance. The machine offers no resistance at terminal extension as isotonic machines do. This resistance is the result of weights being acted upon by gravity in such a way that, even without movement of the limb, the joint musculature must still contract to support the weight. This "back pressure" of isotonics is what enables the exerciser to perform eccentric contractions. Although eccentric contractions are useful in early rehabilitation programs or in gaining muscular strength, there are distinct disadvantages. The residual muscle soreness commonly developed after novel eccentric contractions may cause decreased subsequent performance for up to 72 hours due to biochemical changes in the muscle (Davies, 1984). Eccentric strength is generated by the muscle contracting against a force that is lengthening it. During athletic activity, eccentric muscle contractions play a major role in joint stabilization. An isokinetic device, such as the Cybex II, offers no option for eccentric work. It follows that the Cybex is also unable to diagnostically assess eccentric contractions. The inability to assess a muscle's resistance to stretch may cause the evaluator to miss an important predictor to injury (Elliott, 1978).

The absence of resistance during the deceleration phase of the knee extension (terminal extension) due to the nature of the mechanism and the lack of back pressure eliminating eccentric contractions may neglect adequate strengthening of the musculature active through these specific points in the ROM. Physical therapists, athletic trainers, and anyone concerned with thorough rehabilitation of the injured knee are very aware of the importance of exercising through terminal extension. The last 15^0 is of primary importance, because this is primarily executed by the vastus medialis oblique (VMO) muscle of the quadriceps group (Klein & Allman, 1969). The VMO is the first muscle to show atrophy, and this atrophy will be associatively more pronounced than in the rest of the quadriceps (Brookes, 1983). Lieb and Perry (1971) have demonstrated that the VMO is not totally responsible for terminal extension of the knee, as once was believed. Extension can be executed by the rest of the quadriceps group by way of substitution. However, the VMO is necessary for extension of the knee with proper patellar tracking (Montgomery & Steadman, 1985). The VMO often is the most difficult portion of the quadriceps to rehabilitate following knee injury (Fox, 1975; Santavirta, 1979; Wild, Franklin, & Woods, 1982). Atrophy may persist for many months after the recovery of the rest of the quads (Montgomery & Steadman). Working the last 15^0 of the ROM of knee extension is very important for the complete strengthening of the quadriceps group. The question to be answered is, " Is the knee musculature losing some exercise intensity, especially those structures associated with the extremes in the range of motion, when utilizing the Cybex II isokinetic dynamometer for strength training?"

Strengthening at Specific Joint Angles and the Associated Overflow

Because this investigation is dealing with isometrically testing strength at specific joint angles as the evaluative posttest, it would help to know how specific strength acquisition is. Recent studies have demonstrated that an overflow of strength improvement can occur within 15^0 of the points in the ROM that have been trained (Davies, 1984; Gardner, 1963; Halbach, 1982; Knapik, Mawdsley, & Ramos, 1983; Logan, 1960; Meyers, 1967). These results suggest that it may be difficult to assess a specific joint angle using isometric strength testing, realizing that if the Cybex II was deficient in providing a maximum workload for a specific ROM, the overflow training effect could effectively strengthen into this suspect

ROM. If results tend to support this, the overflow training effect may be substantial enough to compensate for the isokinetic mechanical problems with overloading and, in turn, strengthen the muscle group throughout the entire range of motion.

<u>Isometric Testing as an Evaluative Tool for Dynamically Acquired Strength</u>

A problem an investigator faces when confronting an isokinetic/isotonic comparative strength training investigation is how to test differences of strength acquisition. If the investigator chooses to test isokinetically, the suspect extreme ROMs would be diagnostically tested by the same machine being investigated. The validity of the extreme ROMs has already been questioned (Gregor et al., 1979). To test isotonically would be not only difficult, but biased towards the subjects who trained on the isotonic apparatus (e.g., Nautilus leg extension). The literature seems to be indecisive as to whether static contraction testing is valid for dynamically acquired strength. Moderate to high correlations have been found between isometric and isokinetic torque measures suggesting that, if a person scores well on an isometric test, she/he will also score well on an isokinetic test (Knapik & Ramos, 1980). Positive results were also found in several other investigations (Bender & Kaplan, 1966; Knapik, Wright, et al., 1983). In one study, it was reported that static and dynamic strength were correlated, but the investigators suggested that when evaluating both dynamic and static strength acquisition, testing should also be done both statically and dynamically (Martens & Sharkey, 1966).

Several studies have turned up unfavorable conclusions concerning the evaluation of a dynamic strength training program with static contractions.

Twenty-seven males trained isotonically for 6 weeks with three sets of five repetitions. All subjects were posttested isometrically, in the same manner as they were pretested. The significant increase in isotonic strength was not reflected by the nonsignificant increase with the isometric testing. Therefore it was concluded that isometric scores are not a good indicator of a person's ability to perform isotonic movements (Rasch & Pierson, 1963). Similar results were also found by Berger (1962a).

Inconclusive findings lead to many unanswered questions concerning the appropriateness of utilizing a static contraction pretest/posttest protocol to evaluate strength acquired from dynamic isokinetic and isotonic training sessions. However, due to the apparent impartiality in regard to isotonic and isokinetic training, the maximal isometric contraction pretest/posttest at specific joint angles may be a viable alternative for impartial assessment.

Appropriate Methodology: Exercise Protocol and Equating Workloads

Proper methodology is extremely important in any investigation but it is especially crucial with a comparative study. An investigation needs an efficient and proven strength protocol that applies to both modes of exercise. It is essential that the protocol provide equal workloads and intensities so as not to skew the results. Based on the literature, an investigator must attempt to find an appropriate exercise protocol to comparatively analyze isotonic and isokinetic strength training devices.

Exercise Frequency and Duration

With strength acquisition in mind, it has become commonplace to exercise three times per week with at least 1 day between sessions. This protocol tends to produce significant gains without risking the possibility of chronic fatigue. Significant strength gains can be expected following a program of 6 weeks or longer (Fox, 1979).

Few studies on isokinetic exercise have addressed the optimum frequency associated with strength training (Davies, 1984). Based on the isotonic literature, three times per week with a 1 day rest between appears to provide the optimum strengthening results (Battin & Wyatt, 1980; Davies). Johnson (1980) divided a group of 38 college women into a control group and three strength training groups: (a) slow isokinetic (30^{0}/s), (b) fast isokinetic (180^{0}/s), and (c) isotonic. After 6 weeks of three-per-week workout sessions, he found the slow isokinetic group significantly better than the other three. The important consideration here is that all three exercise groups utilizing the three-per-week sessions for the 6-week program had significant strength gains over the control.

Sets and Repetitions

Now that duration and frequency have been examined, a sound comparative strength investigation needs the correct combination of sets and repetitions for strength training so as to afford the training groups maximum intensity and results without occupying unnecessary time. In a series of extensive strength studies in the 1960s, Berger (1962b;1963) sought to find the most successful work parameters for strength training. In one of his investigations (Berger, 1962b), 9 groups exercised three times per week for 12 weeks, incorporating 1, 2, and 3 sets with 2, 6, and 10 repetitions per set. His results indicated that the program of 3 sets of 6 repetitions was superior for strength development. Berger had similar results in a later study, which also indicated that 3 sets of 6 reps produced better strength developing results (Berger, 1963). In another sets/repetition investigation, O'Shea (1966) used a 6-week progressive weight training program in which each group (3 sets of 9-10 repetitions, 3 sets of 5-6 repetitions, and 3 sets of 2-3 repetitions) had significant static and dynamic strength increases with no significant differences among groups. In his concluding comments, O'Shea stated that the number of reps is not as important as the intensity of the exercise.

A strength training protocol requires a method for adjusting resistance from one workout session to the next. The modified Delorme-Watkins method appears to be an efficient and effective strength training program. Barney and Bangerter (1961) found that, when investigating various isotonic weight adjusting protocols, the Delorme-Watkins method was the only group that produced significant hypertrophy. Although all isotonic adjusting procedures tested by Barney and Bangerter produced significant strength gains, the investigators suggested the use of the Delorme-Watkins method when strength and hypertrophy are desired.

Again isokinetic research is very limited in regard to the number of studies addressing the number of sets and repetitions to be used in a strength training program. One study found no optimum number of repetitions (Magee & Currier, 1984). Six to eight repetitions were equally effective as 10-16 for improving the force developing capacity of muscle through isokinetic exercise training (Magee & Currier). Based on the reviewed literature, it would appear the isotonic and isokinetic strength training groups should be as similar as possible from the training standpoint of sets, repetitions, frequency, and duration.

Rest Intervals

Rest intervals between sets are a major consideration in strength training. The exerciser wants to maximize his/her potential strength development by allowing the muscle to recover adequately. Rest intervals are not regularly documented in most strength training studies, and the optimal rest time between reps, sets, and multiple sets using the Cybex II has not been established (Davies, 1984). During one comparative isotonic/isokinetic investigation, various rest intervals were examined for significant influences upon the strength development results (Campbell, 1974). No significant differences were found between the rest intervals of 0.5, 1.0, and 1.5 minutes.

Equating Workloads

Because overload and intensity are important considerations when organizing a strength training program, it is crucial for a researcher to assure that workloads are as close to identical as possible on both sides of a comparative study. It has been noted in other strength research that equating workloads is necessary but difficult (Delateur et al., 1972; Martens & Sharkey, 1966). This can be especially difficult when comparing different modes of exercise, such as isokinetics and isotonics. Equating sets and repetitions may not be enough. The isokinetic exercise could be a more intense mode of exercise due to its maximum efforts and accomodating nature. Until now, researchers have basically equalized sets, repetitions, frequency, duration, and rest intervals in an attempt to equalize workloads. Ideally a computerized work integrator would be able to assess exactly how much work each subject was completing within a particular exercise mode (Smith & Melton, 1981).

The only aspect of the workload protocol remaining to be analyzed is the appropriate joint speed for strength training. Within the literature already reviewed, it has been revealed that the isokinetic catch-up phenomenon in question is exacerbated by high isokinetic joint speeds. However, the strength training literature reviewed for both isotonics and isokinetics suggested slower joint speeds. The joint speed of typical isotonic exercise is relatively unchanging. The Cybex II can change and adapt its exercise speed with the turn of a knob. The literature revealed that the angular velocity of the knee during most isotonic exercise is approximately 60^{0}/s (Brinkman & Perry, 1982; Davies, 1984; Wyatt & Edwards, 1981). Several studies have found slow isokinetic joint speeds significantly more effective than fast speed isokinetic speeds for strength training programs (Johnson, 1980; Perrine & Edgerton, 1978; Van Oteghen, 1975). The originally published Cybex recommended strength training joint speed was 30^{0}/s (Division of Lumex, Inc., Ronkonkoma, NY). In 1980 they then recommended 60^{0}/s. Six NFL players were tested with three repetitions at 30, 60, 180, 240, and 300^{0}/s (Davies, 1984). Upon analysis of the data, the 30^{0}/s data did not produce any additional information of joint integrity beyond that obtained by testing at 60^{0}/s. Furthermore, approximately 60% of the players had an increase in torque when they went from 30^{0}/s to 60^{0}/s. This may be the result of 30^{0}/s being an unnatural or uncomfortable speed, leading to abnormally high joint compressive loading and creating a force inhibition (Davies, 1984). Utilizing 60^{0}/s not only would be following the isokinetic strength training recommendations from Cybex and the literature but it also would serve to approximately equate the joint angle speed at which the isotonic and isokinetic groups will be training. For the benefit of any people involved in rehabilitation, the literature notes that training at only 60^{0}/s may leave as much as a 20% deficiency (Sherman, Pearson, Plyley, Costill, Habansky, Vogelgesang, 1982). One should train throughout the velocity spectrum to ensure the most complete rehabilitation possible with regard to speed of movement (Davies, 1984).

Summary

Since the introduction of the isokinetic dynamometer, investigators have searched for a clear answer as to which mode of exercise was more thorough, isokinetic or isotonic. The advantages of isotonics and isokinetics were listed and considered. The body of literature comparing isokinetic and isotonic exercise reviewed is far from conclusive. The conclusions span the spectrum of possible outcomes. As a result, the isokinetic research findings were analyzed, and some of the theoretical claims were questioned. Due to the nature of the isokinetic joint acceleration and deceleration phenomenon inherent in the machinery, a question of adequate intensity of training presents itself in the extreme points of the ROM of knee extension.

Methodologies were examined by reviewing the literature concerning isotonic/isokinetic comparative strength programs. The strength training literature concerning the most appropriate sets, repetitions, duration, frequency, and rest intervals was reviewed with constant concern about equating the workloads of the two exercising groups, but very little research concerning these has been done specifically for isokinetic exercise. The assumption is constantly made that effective isotonic protocols will be just as effective when used with isokinetic exercise.

Chapter 3

METHODS AND PROCEDURES

This chapter outlines the methods and procedures used in this study. Specifically, this chapter deals with (a) selection of subjects, (b) testing instruments, (c) testing procedures, (d) data collection and scoring methods, and (e) treatment of data.

Selection of Subjects

The subjects were recruited through a prepared announcement (Appendix A) read aloud by the class instructor in physical education classes at the SUNY College at Cortland. After an initial list was organized, the volunteers met as a group to be informed of the nature of the study and were requested to participate. All participating subjects were asked to individually read and sign an informed consent form describing the testing procedures (Appendix B). Subjects also completed a questionnaire concerning their general health (e.g., blood pressure) and the specific history of their knee joints (Appendix C). Only individuals with knee joints free of injury or history of debilitating degenerative diseases of the joint were used in this study.

A total of 22 students volunteered to participate, but 12 actually completed the study. Attrition was caused by failure to exercise regularly and/or inability to be present for posttesting.

Testing Instruments

The following instruments were used for data collection in this study.

Cybex II Dynamometer

This isokinetic exercise device utilizes the principle of constant speed and accommodating resistance to provide muscular exercise. It resists the involved muscle group proportionately to the amount of force exerted by the muscle group. Previous investigation has shown the measurement of contractile muscle strength and endurance by the Cybex II to be reliable and valid (Moffroid et al., 1969). By utilizing various speed settings, the Cybex II can be used to test and train muscle strength (30-60^{0}/s), muscular power (120-180^{0}/s), or muscular endurance (180-300^{0}/s). A setting of 60^{0}/s was used to train the knee extensors in the Cybex II group for strength. The pretest and posttest strength assessment was carried out for both the Cybex II and Nautilus trained groups by utilizing isometric contractions of the knee extensors on the Cybex II at five joint angle positions for each leg (85^{0}, 95^{0}, 150^{0},160^{0}, 170^{0}). Paper speed was 0 mm/s, which allowed the creation of a histogram by the dual channel recorder. Each line created by the heated stylus on the graph paper indicated peak torque achieved at a specific joint angle. After a joint angle position was recorded, the paper was advanced enough to allow sufficient space for the peak torque recording at the next joint angle position .

Nautilus Leg Extension Machine

Nautilus machines are known as variable resistance isotonic exercise devices. These isotonic machines vary the resistance to correspond to the changes in the muscular strength and leverage advantages throughout the range of motion. Theoretically, the shape of the Nautilus cam utilized in the leg extension machine will more effectively provide maximum intensity throughout the entire range of motion as compared to traditional isotonic exercise equipment. In this study, the Nautilus training group performed one-legged knee extensions with a 2-count extension phase, a 1-count hold in terminal extension, and a 4-count negative-descending phase for each repetition performed.

Testing Procedures

Upon granting consent, the subjects ($\underline{N}$ = 12) were randomly assigned, using a table of random numbers, to either the Nautilus training group (female $\underline{n}$ = 4; male $\underline{n}$ = 2) or the Cybex II training group (female $\underline{n}$ = 3; male $\underline{n}$ = 3). Each subject was familiarized with the apparatus she/he would be training on prior to the pretest. During this familiarization process, each subject scheduled appointments for his/her pretesting session.

Upon arriving at the laboratory, the subject was placed on the Cybex II dynamometer in the sitting position. After proper fixation with belts on the chest, pelvis, and thigh, the subject was allowed to warm-up the limb with five repetitions at 60^{o}/s. Peak torque output during warm-up was noted so as to facilitate the choice of which foot-pound scale to utilize (180 or 360 ft-lb). The dual channel recorder was then prepared by setting the baseline at 0^{o}, or anatomical zero (terminal extension). The first joint angle position was established by having the subject fully flex the knee, with the heel positioned against the base pad of the Cybex II testing table. This was the baseline position for all subjects' joint angle positions. The subject was then instructed to maximally extend the knee gradually and as steadily as possible until he/she was exerting maximal force. The investigator instructed the subject to cease the contraction as soon as the peak torque readout failed to continue to increase. The subject was then given a 2-minute rest interval before another isometric test at the next joint angle. During this rest interval, the investigator positioned the limb at the next joint angle by utilizing the Cybex II electrogoniometer. After the first reading, the angle was increased 10^{0} (95^{0}) to have two readings within the first 20^{0} of extension. These points in the range of motion are of particular interest because of the question of whether the Cybex II offers adequately intense resistance during the limb's initial acceleration phase. A reading was then taken at 150^{0} to have a comparative point within the range of motion of knee extension that was not within the extremes in question. The final two joint angles tested were 10^{0} and 20^{0} from terminal extension (i.e., 170^{0} and 160^{0}). This procedure was repeated until each maximal isometric contraction at each of the five joint angles was recorded for each limb. The same Cybex II apparatus was used for all subjects tested.

The groups' training regimens were performed as follows. Both groups trained using a 2-minute rest interval between sets. The investigator also stressed the importance of proper exercise form throughout the training regimens.

1. The Cybex II isokinetic group exercised three times per week, performing three maximal sets of six repetitions of leg extension and leg flexion exercises bilaterally, one leg at a time, at 60^{0}/s.

2. The Nautilus isotonic group performed three sets of six repetitions of leg extensions bilaterally, one leg at a time, progressively increasing the weight load when six repetitions were achieved in the third and final set.

Initial workloads were estimated individually for each leg by establishing a load that provided a challenging 10-repetition set for the subject. Resistance progressions were in increments of 5 to 10 pounds, depending on the ease of completion of the final set. Nautilus subjects were also advised to utilize a similar exercise program for the hamstrings, because hamstring work was not inherently provided with the Nautilus workout as it was for the Cybex II group. It was the investigator's intention to avoid tampering with the quadriceps:hamstring strength ratios of the subjects.

Scoring of Data

Peak torque units were recorded using the Cybex II chart data card by matching the proper grid scale to the Cybex II recording printout. A peak torque was calculated and labelled on the graph readout paper bilaterally for each of the five extension joint positions for each subject. This data scoring procedure was identical for both groups during the pretest and posttest.

Treatment of Data

For each angle, a Group by Sex by Leg by Time analysis of variance (ANOVA) was run to determine if a significant change in peak torque occurred over the training period. Because of differences in the gender make-up of the groups and possible pronounced differences in the pretest scores, a Group by Sex by Leg analysis of covariance (ANCOVA) was run on posttest peak torque, with pretest peak torque scores as covariates to determine if significant differences in strength acquisition occurred as a result of the two different training techniques. All tests were run at the .05 level of significance.

Chapter 4

ANALYSIS OF DATA

This study was conducted to compare effects of isotonic and isokinetic training upon strength at specific joint angles during knee extension. A four-way ANOVA (Group by Sex by Leg by Time) was run at each joint angle to identify if significant changes had taken place over the training period. Subsequently, an ANCOVA was used to identify any statistically significant group differences that might exist in strength acquisition at specific joint angles, using a Group by Sex by Leg design with pretraining strength as the covariate. This chapter includes an analysis at each joint angle with respect to (a) Nautilus versus Cybex II, (b) male versus female, and (c) right leg versus left leg comparisons. All analyses were tested at the .05 level of significance.

ANOVA Pretest/Posttest Differences

To identify significant change in peak torque readings during the training period, a four-way ANOVA (Group by Sex by Leg by Time) was run at each joint angle (85^{o}, 95^{o}, 150^{o}, 160^{o}, and 170^{o}). The results are seen in Tables 1-5.

There was significant change at three of the angles: (a) 85^{o}, (b) 95^{o}, and (c) 170^{o}. The changes at 150^{o} and 160^{o} were not significant, suggesting that a noticeable strength acquisition was not evident at these joint angles.

Other significant $\underline{F}$ values seen in these tables indicate several points that were expected. For example, the male scores were significantly higher than the female scores. There were some group differences seen, but because of unequal distribution of males and females in the groups and the

Table 1

ANOVA Summary Table for 85°

	SS	df	MS	F
Between Subjects				
Within Cells	6595.08	8	824.39	
Constant	1013790.00	1	1013790.00	1229.75*
Group	20862.59	1	20862.59	25.31*
Sex	90595.10	1	90595.10	109.89*
Group by Sex	23061.57	1	23061.57	27.97*
"TIME" Within Subjects				
Within Cells	1569.17	8	196.15	
Time	1315.31	1	1315.31	6.71*
Group by Time	59.31	1	59.31	0.30
Sex by Time	0.49	1	0.49	0.00
Group by Sex by Time	520.96	1	520.96	2.66
"LEG" Within Subjects				
Within Cells	1637.67	8	204.71	
Leg	72.96	1	72.96	0.36
Group by Leg	336.49	1	336.49	1.64
Sex by Leg	16.49	1	16.49	0.08
Group by Sex by Leg	586.84	1	586.84	2.87

(table continues)

Table 1

ANOVA Summary Table for 85°

	SS	df	MS	F
"TIME BY LEG" Within Subjects				
Within Cells	1708.92	8	213.61	
Time by Leg	218.24	1	218.24	1.02
Group by Time by Leg	719.06	1	719.06	3.37
Sex by Time by Leg	344.24	1	344.24	1.61
Group by Sex by Time by Leg	653.06	1	653.06	3.06

*$p < .05$.

Table 2

ANOVA Summary Table for 95^0

	SS	df	MS	F
Between Subjects				
Within Cells	8832.31	8	1104.04	
Constant	1305840.01	1	1305840.01	1182.78*
Group	39273.19	1	39273.19	35.57*
Sex	119456.04	1	119456.04	108.20*
Group by Sex	33738.98	1	33738.98	30.56*
"TIME" Within Subjects				
Within Cells	2020.65	8	252.58	
Time	1448.00	1	1448.00	5.73*
Group by Time	100.94	1	100.94	0.40
Sex by Time	183.54	1	183.54	0.73
Group by Sex by Time	481.78	1	481.78	1.91
"LEG" Within Subjects				
Within Cells	2573.65	8	321.71	
Leg	207.01	1	207.01	0.64
Group by Leg	35.83	1	35.83	0.11
Sex by Leg	84.77	1	84.77	0.26
Group by Sex by Leg	174.18	1	174.18	0.54

(table continues)

Table 2

ANOVA Summary Table for 95°

	SS	df	MS	F
"TIME BY LEG" Within Subjects				
Within Cells	789.48	8	98.68	
Time by Leg	193.15	1	193.15	1.96
Group by Time by Leg	19.15	1	19.15	0.19
Sex by Time by Leg	35.00	1	35.00	0.35
Group by Sex by Time by Leg	236.18	1	236.18	2.39

*$p < .05$.

Table 3

ANOVA Summary Table for 150°

	SS	df	MS	F
Between Subjects				
Within Cells	2691.58	8	336.45	
Constant	406377.57	1	406377.57	1207.85*
Group	2562.40	1	2562.40	7.62*
Sex	23617.77	1	23617.77	70.20*
Group by Sex	3208.24	1	3208.24	9.54*
"TIME" Within Subjects				
Within Cells	371.83	8	46.48	
Time	119.29	1	119.29	2.57
Group by Time	477.18	1	477.18	10.27*
Sex by Time	90.67	1	90.67	1.95
Group by Sex by Time	49.02	1	49.02	1.05
"LEG" Within Subjects				
Within Cells	374.42	8	46.80	
Leg	108.83	1	108.83	2.33
Group by Leg	44.24	1	44.24	0.95
Sex by Leg	171.42	1	171.42	3.66
Group by Sex by Leg	182.59	1	182.59	3.90

(table continues)

Table 3

ANOVA Summary Table for 150°

	SS	df	MS	F
"TIME BY LEG" Within Subjects				
Within Cells	298.67	8	37.33	
Time by Leg	155.31	1	155.31	4.16
Group by Time by Leg	0.96	1	0.96	0.03
Sex by Time by Leg	36.25	1	36.25	0.97
Group by Sex by Time by Leg	0.49	1	0.49	0.01

*$p < .05$.

Table 4

ANOVA Summary Table for 160°

	SS	df	MS	F
Between Subjects				
Within Cells	2025.04	8	253.13	
Constant	137073.25	1	137073.25	541.51*
Group	220.31	1	220.31	0.87
Sex	10535.08	1	10535.08	41.62*
Group by Sex	923.31	1	923.31	3.65
"TIME" Within Subjects				
Within Cells	895.63	8	111.95	
Time	415.10	1	415.10	3.71
Group by Time	89.34	1	89.34	0.80
Sex by Time	32.16	1	32.16	0.29
Group by Sex by Time	97.46	1	97.46	0.87
"LEG" Within Subjects				
Within Cells	925.71	8	115.71	
Leg	15.37	1	15.37	0.13
Group by Leg	41.49	1	41.49	0.36
Sex by Leg	51.00	1	51.00	0.44
Group by Sex by Leg	29.82	1	29.82	0.26

(table continues)

Table 4

ANOVA Summary Table for 160°

	SS	df	MS	F
"TIME BY LEG" Within Subjects				
Within Cells	326.29	8	40.72	
Time by Leg	226.59	1	226.59	5.56*
Group by Time by Leg	190.24	1	190.24	4.66
Sex by Time by Leg	202.00	1	202.00	4.95
Group by Sex by Time by Leg	127.06	1	127.06	3.12

*$p < .05$.

Table 5

ANOVA Summary Table for 170^{o}

	SS	df	MS	F
Between Subjects				
Within Cells	4158.29	8	519.79	
Constant	242742.00	1	242742.00	467.00*
Group	2.59	1	2.59	0.00
Sex	17270.24	1	17270.24	33.23*
Group by Sex	178.83	1	178.83	0.34
"TIME" Within Subjects				
Within Cells	1388.96	8	173.62	
Time	1032.75	1	1032.75	5.95*
Group by Time	37.10	1	37.10	0.21
Sex by Time	11.77	1	11.77	0.07
Group by Sex by Time	9.06	1	9.06	0.05
"LEG" Within Subjects				
Within Cells	211.29	8	26.41	
Leg	29.06	1	29.06	1.10
Group by Leg	26.12	1	26.12	0.99
Sex by Leg	167.77	1	167.77	6.35*
Group by Sex by Leg	17.06	1	17.06	0.65

(table continues)

Table 5

ANOVA Summary Table for 170°

	SS	df	MS	F
"TIME BY LEG" Within Subjects				
Within Cells	679.96	8	84.99	
Time by Leg	289.46	1	289.46	3.41
Group by Time by Leg	15.93	1	15.93	0.19
Sex by Time by Leg	226.59	1	226.59	2.67
Group by Sex by Time by Leg	94.71	1	94.71	1.11

*$p < .05$.

possible inequality of pretest scores, these should be disregarded. Instead, an ANCOVA would be appropriate in order to assume that group results are not biased by these inequalities.

Full Analysis at 85^0 of Extension

Descriptive Data

A review of the descriptive raw data was done to examine the data for any notable tendencies. Descriptive data for all comparisons are found in Table 6. As might be expected, at 85^0 the male maximal torque means were higher than the female's for both the Cybex and Nautilus groups and for both the right and left legs. One unusual note was that the male Nautilus group decreased their maximal torque mean from pretest to postest with the right leg. This tendency did not exist with the female Nautilus group, nor did it present itself with the male or female Cybex II groups from pretest to posttest.

ANCOVA Results for 85^0

The ANCOVA results for 85^0 are illustrated in Table 7. The three-way interaction of Group by Leg by Sex was not significant at $p < .05$. All two-way interactions (i.e., Group by Leg, Group by Sex, and Leg by Sex) were also found not to be statistically significant, therefore the main effects were analyzed.

The main effects consist of the Group, Sex, and Leg comparisons. At 85^0, no significant statistical difference was found for Group, Sex, or Leg.

Table 6

Peak Torque Raw Scores for Each Angle Tested

	n	Pretest ($M \pm SD$) Right	Pretest ($M \pm SD$) Left	Posttest ($M \pm SD$) Right	Posttest ($M \pm SD$) Left
85^0					
Nautilus					
Male	2	169.50 ± 19.09	130.00 ± 19.80	145.50 ± 2.12	157.00 ± 29.70
Female	4	99.00 ± 4.69	97.75 ± 14.66	115.25 ± 10.50	112.50 ± 10.66
Cybex					
Male	3	220.33 ± 15.04	237.33 ± 39.58	245.67 ± 19.86	251.33 ± 19.86
Female	3	102.67 ± 11.67	98.67 ± 24.99	110.67 ± 22.50	103.67 ± 19.86
95^0					
Nautilus					
Male	2	170.50 ± 38.89	155.00 ± 29.70	166.00 ± 5.66	167.00 ± 1.41
Female	4	107.75 ± 23.71	100.25 ± 11.79	130.00 ± 29.69	127.75 ± 15.97
Cybex					
Male	3	269.00 ± 9.64	276.67 ± 35.30	283.33 ± 7.02	284.00 ± 15.40
Female	3	127.00 ± 21.63	108.67 ± 24.03	123.67 ± 9.29	123.67 ± 19.50

(table continues)

Table 6

Peak Torque Raw Scores for Each Angle Tested

	n	Pretest (M ± SD) Right	Pretest (M ± SD) Left	Posttest (M ± SD) Right	Posttest (M ± SD) Left
150°					
Nautilus					
Male	2	104.00 ± 11.31	97.00 ± 7.07	100.50 ± 7.78	105.50 ± 6.36
Female	4	72.50 ± 11.79	69.25 ± 12.97	74.50 ± 13.63	75.25 ± 9.54
Cybex					
Male	3	150.00 ± 6.00	132.00 ± 15.62	130.33 ± 11.02	122.33 ± 6.81
Female	3	73.00 ± 14.73	74.00 ± 9.54	66.33 ± 9.50	71.00 ± 2.65
160°					
Nautilus					
Male	2	62.00 ± 5.66	61.00 ± 9.90	65.00 ± 8.49	66.50 ± 9.19
Female	4	34.50 ± 8.89	36.25 ± 9.00	48.50 ± 13.18	49.25 ± 7.93
Cybex					
Male	3	86.33 ± 21.03	63.33 ± 18.58	74.67 ± 7.37	84.00 ± 20.79
Female	3	36.67 ± 3.22	36.33 ± 4.51	37.67 ± 5.13	39.33 ± 4.16

(table continues)

Table 6

Peak Torque Raw Scores for Each Angle Tested

	n	Pretest ($\underline{M} \pm \underline{SD}$) Right	Pretest ($\underline{M} \pm \underline{SD}$) Left	Posttest ($\underline{M} \pm \underline{SD}$) Right	Posttest ($\underline{M} \pm \underline{SD}$) Left
170°					
Nautilus					
Male	2	93.50 ± 13.44	76.50 ± 4.95	93.50 ± 13.44	99.00 ± 12.73
Female	4	48.25 ± 10.62	51.25 ± 10.24	63.25 ± 11.47	59.25 ± 12.37
Cybex					
Male	3	98.67 ± 16.80	85.67 ± 23.80	96.67 ± 17.65	99.33 ± 19.43
Female	3	47.00 ± 7.81	47.33 ± 3.05	52.00 ± 17.44	61.67 ± 16.77

Note. All measurements are ft-lb.

Table 7

ANCOVA Summary Table for 85^{0}

	SS	df	MS	F
Between Subjects				
Within Cells	2665.20	7	380.74	
Regression	1633.76	1	1633.76	4.29
Constant	691.17	1	691.17	1.82
Group	584.99	1	584.99	1.54
Sex	424.60	1	424.60	1.12
Group by Sex	1306.93	1	1306.93	3.43
Within Subjects				
Within Cells	637.49	7	91.07	
Regression	0.47	1	0.47	0.01
Leg	15.95	1	15.95	0.18
Group by Leg	22.54	1	22.54	0.25
Sex by Leg	242.03	1	242.03	2.66
Group by Sex by Leg	0.16	1	0.16	0.00

Summary of Analyses at All Other Joint Angles

Descriptive Data

Tendencies noticed when the raw data of the remaining joint angles were reviewed included:

1. Male maximal torque means for both the Cybex II and Nautilus groups were consistently higher than those of the females of those groups at all angles.

2. The torque means decreased for the male Nautilus group's right leg from pretest to posttest at 95^0 and 150^0.

3. The female Cybex II group's torque means decreased from pretest to posttest at 95^0.

4. The torque means decreased for the Cybex group for both the males' and females' left and right legs at 150^0.

5. The maximal torque means for the male Cybex II group's right leg decreased from pretest to posttest at 160^0.

6. At 170^0, the male Nautilus group's right leg torque means did not change from pretest to posttest.

7. The male Cybex II group's torque means at 170^0 decreased from pretest to posttest,

8. Aside from those mentioned, all groups showed a torque mean increase from pretest to posttest.

ANCOVA Results

The same procedure was followed for 95^0, 150^0, 160^0, and 170^0 as was for 85^0. These data are found in Tables 8-11. No statistically significant differences were found in any of the interactions or the main effects

Table 8

ANCOVA Summary Table for 95^{0}

	SS	df	MS	F
Between Subjects				
Within Cells	2052.04	7	293.15	
Regression	1614.00	1	1614.00	5.51
Constant	2514.73	1	2514.73	8.58*
Group	996.16	1	996.16	3.40
Sex	1313.34	1	1313.34	4.48
Group by Sex	2950.17	1	2950.17	10.06*
Within Subjects				
Within Cells	900.18	7	128.60	
Regression	382.53	1	382.53	2.97
Leg	56.81	1	56.81	0.44
Group by Leg	3.91	1	3.91	0.03
Sex by Leg	4.84	1	4.84	0.04
Group by Sex by Leg	86.91	1	86.91	0.68

*$p < .05$.

Table 9

ANCOVA Summary Table for 150°

	SS	*df*	*MS*	*F*
Between Subjects				
Within Cells	532.00	7	76.00	
Regression	759.04	1	759.04	9.99*
Constant	170.97	1	170.97	2.25
Group	70.06	1	70.06	0.92
Sex	81.95	1	81.95	1.08
Group by Sex	14.90	1	14.90	0.20
Within Subjects				
Within Cells	166.86	7	23.84	
Regression	2.85	1	2.85	0.12
Leg	4.63	1	4.63	0.19
Group by Leg	25.15	1	25.15	1.06
Sex by Leg	11.64	1	11.64	0.49
Group by Sex by Leg	75.46	1	75.46	3.17

*$p < .05$.

Table 10

ANCOVA Summary Table for 160°

	SS	df	MS	F
Between Subjects				
Within Cells	890.39	7	127.20	
Regression	171.57	1	171.57	1.35
Constant	1191.32	1	1191.32	9.37*
Group	1.71	1	1.71	0.01
Sex	493.77	1	493.77	3.88
Group by Sex	520.00	1	520.00	4.09
Within Subjects				
Within Cells	632.61	7	90.37	
Regression	231.68	1	231.68	2.56
Leg	227.28	1	227.28	2.51
Group by Leg	173.00	1	173.00	1.91
Sex by Leg	175.04	1	175.04	1.94
Group by Sex by Leg	129.10	1	129.10	1.43

*$p < .05$.

Table 11

ANCOVA Summary Table for 170°

	SS	df	MS	F
Between Subjects				
Within Cells	2557.53	7	365.36	
Regression	931.56	1	931.56	0.15
Constant	439.92	1	439.92	0.31
Group	46.02	1	46.02	0.73
Sex	128.17	1	128.17	0.57
Group by Sex	0.20	1	0.20	0.98
Within Subjects				
Within Cells	166.89	7	23.84	
Regression	86.02	1	86.02	0.10
Leg	4.14	1	4.14	0.69
Group by Leg	45.20	1	45.20	0.21
Sex by Leg	20.73	1	20.73	0.38
Group by Sex by Leg	68.03	1	68.03	0.14

for the final four joint angles tested. However at 95^{0}, the Group by Sex interaction was significant. Using the adjusted mean for 95^{0}, the males' Nautilus score (236.54 ft-lb) was much lower than the male Cybex II score (328.46 ft-lb). However, for the females, the Nautilus adjusted mean (222.71 ft-lb) was slightly greater than the Cybex II adjusted mean (206.07 ft-lb). The males increased greatly, yet the females actually decreased slightly, causing a significant Group by Sex interaction. However, this is not a disordinal interaction. In other words, the means of the male and female groups do not have the same slope when they are plotted. In both cases the mean for the males is always higher than the mean for the females from one group to the other. The only finding affected is that the group effect would possibly have been significant if the males' pattern had also been followed by the females.

Chapter 5

DISCUSSION

The purpose of this study was to investigate isotonic and isokinetic training effects upon strength at specific joint angles (85^0, 95^0, 150^0, 160^0, and 170^0) during knee extension. A four-way ANOVA (Group by Sex by Leg by Time) was used to to identify if significant changes had taken place over the training period. Subsequently, a three-way ANCOVA (Group by Sex by Leg) was used to identify any statistically significant group differences that existed in strength acquisition at specific joint angles.

ANOVA revealed statistically significant improvements in strength acquisition from pretest to posttest at the extreme joint angles (85^0, 95^0, and 170^0) tested. Statistically significant results were not shown for joint angles 150^0 and 160^0. A trend towards increased strength was apparent at 160^0. At 150^0, pretest to posttest torque means decreased in five out of the eight cells (male Nautilus right leg, male Cybex II right leg, male Cybex II left leg, and female Cybex II right and left legs). Why this phenomenon occurred is difficult to substantiate physiologically. The midrange joint angles should receive optimal resistance on both the Cybex II and the Nautilus leg extension machine. It may be, as suggested by Rasch and Pierson (1963) and Berger (1962a), that isometric scores are not good indicators for dynamically acquired strength. The strength increases acquired through the training period with the Cybex II and the Nautilus leg extension machine may not be reflected proportionately and/or accurately by the isometric contractions. This alone may have been enough to mask a training effect. However, if the validity of isometric joint angle testing as related to dynamic strength training is questioned, the validity of the significant improvements in strength with training at the other joint angles (85°, 95°, and 170°) must also be questioned.

With respect to strength acquisition between groups, no significant differences were found at any joint angle tested. Therefore, the null hypothesis was accepted. Both the isotonic and isokinetic groups improved in strength at the majority of angles tested with no significant differences between groups. Both the Cybex II isokinetic dynamometer and the Nautilus leg extension machine were shown to be, for the most part, effective strength training devices. This was especially true for the extreme points in the ROM (85°, 95°, and 170°) for knee extension. This indicates that the Cybex II was as effective as the Nautilus leg extension training even at points in the ROM where the machine is said to be accelerating/decelerating, despite the fact that previous literature (Gregor et al.,1979; Knapik, Wright, et al., 1983; Sapega et al., 1982; Winter et al., 1981) suggested the Cybex may not provide optimal resistance during its acceleration and deceleration phases. It is possible that the absence of significant group differences could be due partially to the use of maximal isometric contractions to evaluate dynamically acquired strength. As previously mentioned, the capability of the isometric testing to assess dynamically acquired strength has been questioned (Berger, 1962a; Rasch & Pierson, 1963). More likely, the explanation behind the success of the Cybex to equally strengthen the extremes of the knee extension ROM is due to an overflow training effect. Recent studies have demonstrated that an overflow of strength improvement can occur within 15° of the points in the ROM that have been trained (Davies, 1984; Gardner, 1963; Halbach, 1982; Knapik, Mawdsley, et al., 1983; Logan, 1960; Meyers, 1967). If indeed there is a minimal overflow of 15^{o}, this may be sufficient to carry over into the suspect extremes in the ROM and effectively strengthen those areas associated with the acceleration and deceleration of the Cybex II. In other words, the dynamic strengthening process may not be physiologically specific enough to be concerned with the small amount of ROM that might be affected by the acceleration and deceleration of the Cybex II. Due to the nature of the exercise overflow, exercising a limb isokinetically through the majority of the functional ROM would allow for adequate overload and strengthening through the involved ROM and the additional extreme portions of the ROM, even though the machine may not specifically provide optimal resistance at these points.

It also should be mentioned that very small groups, as used in this study, limit the likelihood of finding significance if minor differences exist between groups. The differences have to be fairly great to show up when using such a small N. It would be informative to have a similar study carried out with larger subject groups to provide a more powerful analysis of potentially small between-group differences.

Both modes of exercise, isotonics and isokinetics, have inherent advantages in regard to uses in strength training and rehabilitation. As suggested in some of the strength training literature (Delateur et al., 1972; Girardi, 1971; Hoffman, 1971; Shields et al.,1985), it is apparent that little or no difference exists between isokinetic and isotonic strength training. In this investigation, both training methods effectively strengthened the extensors of the knee, including the important extreme points in the ROM.

Therefore it is suggested that choice of the appropriate strength training device should be made in accordance with (a) availabiltiy of the machine, (b) efficiency (i.e., setup time, supervision), and (c) the specific needs of the patient or athlete.

The results of this investigation indicate that, even though some previous evidence suggested that the Cybex II isokinetic dynamometer may not provide optimal resistance during its acceleration and deceleration phases (Gregor et al., 1979; Knapik, Wright et al., 1983; Sapega et al., 1982; Winter et al., 1981), it did strengthen the knee extensors at these extremes in the ROM (85^0, 95^0, and 170^0). Overall it proved as effective as the Nautilus variable-resistance isotonic leg extension machine following 7 weeks of regular training. The results may be best explained by the exercise overflow phenomenon, which indicates strength improvement can occur within 15^0 of the points in the ROM that have been trained. Therefore the Cybex was effective, although it possibly offered less than optimal resistance in the extremes of the ROM.

Chapter 6

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

Summary

The purpose of this study was to investigate isotonic and isokinetic training effects upon strength at specific joint angles (85^0, 95^0, 150^0, 160^0, and 170^0) during knee extension. The subjects were 12 SUNY College at Cortland students (7 females, 5 males).

The study consisted of two strength training groups, Cybex II isokinetic dynamometer and the Nautilus variable-resistance isotonic leg extension machine. Each group was randomly assigned 6 subjects who trained both legs for a 7-week period. The Cybex group trained at 60^0/s executing three sets of six repetitions, three times per week. The Nautilus group used a modified Delorme-Watkins training protocol, also performing three sets of six repetitions, three times per week. Both legs of the subjects were pretested and posttested using maximal isometric contractions performed on the Cybex II at 85^0, 95^0, 150^0, 160^0, and 170^0 of knee extension. All testing and training was completed at Park Physical Education and Recreation Center, SUNY College at Cortland. All test performances were quantified by the Cybex II pen recording device and interpreted manually using the Cybex chart data card. A four-way ANOVA (Group by Sex by Leg by Time) was run at each joint angle to identify if significant changes had taken place over the training period. Subsequently, an ANCOVA was used to identify any statistically significant differences that might exist in strength acquisition at specific joint angles, using a Group by Sex by Leg design with pretraining strength as the covariate.

Although some previous evidence suggested that the Cybex II isokinetic dynamometer may not provide optimal resistance during its acceleration and deceleration phases, the results of the present study indicated that it conditioned the extreme points in the ROM during knee extension as effectively as the Nautilus training. In this study the Cybex provided an adequate challenge to knee extension during the acceleration and deceleration phases and allows strength enhancement.

Conclusion

The results of this study supported the following conclusion:

1. The Cybex II isokinetic dynamometer is as effective as the Nautilus leg extension machine in strengthening the knee extensors throughout the entire ROM.

Recommendations

The findings of this investigation led to these recommendations:

1. A similar study should be conducted involving a larger number of subjects to improve the possibility of detecting small differences that might exist between training groups.

2. Further investigation should be directed towards equating workloads when carrying out comparative studies of different strength training methods. Equating repetitions and sets may not be accurate enough for reliable results.

3. Further research needs to be done concerning optimal repetitions, sets, and rest intervals specifically for isokinetic strength training. Utilizing the existing literature regarding isotonics and applying it to

isokinetics does not seem to be an appropriate procedure on which to establish a methodology.

4. Another study should be conducted using an impartial alternative to isometric pretesting and posttesting. Preferably, a dynamic assessment should be used when evaluating dynamically acquired strength.

Appendix A

RECRUITMENT MESSAGE

(Read by Investigator)

I am currently conducting a research project designed to determine if there is a significant difference between isokinetic (Cybex II) and isotonic variable resistance (Nautilus) exercise with respect to strengthening the knee joint through an entire range of motion. Your participation will require you to schedule 20-minute workout sessions, three times a week, for a period of 7 weeks. There will be an organizational meeting and pretesting session to attend before you begin any exercise bouts. At the end of the 7 weeks of training, a posttesting session will conclude your participation in the study. During each of your visits, you will be asked to perform three sets of 10 repetitions of leg extensions, isolating each leg, on either the Cybex or Nautilus machine. Upon completion of this project, you will have worked on improving your leg strength on two of the present state-of-the-art strengthening devices. This experiment has no bearing on your standing in this class. If you are interested in learning more about participating in this project please write your name and phone number on this sheet. We will have our information meeting on ________ to tell you more about the experiment and schedule your training sessions.

Appendix B

INFORMED CONSENT FORM

State University College at Cortland

We request your informed consent to be a participant in the project described below. Please feel free to ask about the project, its procedures, or objectives

At any time during the course of the project, you may, without prejudice, withdraw this consent and discontinue your participation in the project or activity.

The privacy of each participant will be protected, and all information will be treated with appropriate confidentiality.

In some experiments, it may be necessary to withhold certain information in the interests of the particular research. Should this occur, at the end of the experiment all individuals will be furnished a full explanation of the purpose and design of the project.

The faculty member responsible for this project is John Cottone (Gary Sforzo; Ithaca College) of the Physical Education department.

(A) The procedure to be followed, and their purposes, including identification of any procedures which are experimental:

All questions are addressed on the following attached pages.

(B) The attendant discomforts and risks reasonably to be experienced:

(C) The benefits to be expected:

(D) Alternative procedures that might be advantageous to the subject: (If there are other experimental procedures which might be used with less risk or discomfort, please explain.)

****

I have read the description of the activity or project for which this consent is requested, and I consent to participate.

TITLE OF PROJECT A Comparison of Variable Resistance and Isokinetic Training for Strength Improvements Within Selected Ranges of Motion During the Extension of the Knee.

Date: 3/3/87 Signature________________________

Appendix B (continued)

A) <u>The procedure to be followed, and their purposes, including identification of any procedures which are experimental:</u>

You will be asked to meet once as a group for organizational purposes. At your first appointment we will take some pretest strength readings. These pretest sessions involve taking 12 maximal strength readings at 12 points in your knee range of motion. Each of these meetings should not last more than an hour. You will be asked to make workout appointments for three times/week, for a 7-week period, each workout appointment lasting about 20 minutes. During which you will be asked to perform leg extensions three sets of 10 with both legs, either on a Nautilus leg extension machine, or on a Cybex II Isokinetic Dynamometer for the duration of the 7 weeks. At the end of the 7 weeks, the group will be reassembled for a posttesting session performed precisely the same as the pretesting session. You will be told in advance which resistance exercise machine you will be working with. Consistent attendance is essential. If you think you may miss more than a couple of sessions, please reconsider volunteering.

B) <u>The attendant discomforts and risks reasonably to be experienced</u>:

There are no great risks associated with participation in this research. Certainly, there is minimal risk involved in any exercise session; you may experience some temporary discomfort due to muscle fatigue or soreness. Additionally, there is the risk of joint injury during maximal muscle contractions. If you experience any significant discomfort within your knees or other related parts of your body you are free to discontinue

Appendix B (continued)

participating. To minimize the risks outlined, your exercise bouts will always be overseen by a certified athletic trainer or an athletic training student.

C) The benefits to be expected:

The purpose of this study will be to train your legs with resistive-type exercises and record resulting strength readings in order to compare and contrast them with the pretraining strength readings. Determining if a particular mode of resistive exercise strengthens the joint musculature significantly, and equally, throughout the full range of motion could provide valuable research information. It is important that a resistive exercise strengthen the joint through a complete range of motion. Upon completion of this project, you will have have worked on improving your leg strength on two of the present state-of-the-art strengthening devices.

D) Alternative procedures that might be advantageous to the subject: (If there are other experimental procedures which might be used with less risk or discomfort please explain.)

At this point in time no design changes that would further reduce risk and subject discomfort can be suggested. If such adjustments become available prior to commencement of this project and they can be made while retaining the integrity of the experiment, these design changes will be made. Any such changes will be reported to the Human Subjects Committee.

Appendix C

SUBJECT QUESTIONNAIRE

1. Have you ever had problems with either of your knees?

YES ☐ or NO ☐

If Yes, please elaborate ____

____

2. Have you ever had surgery performed on either of your knees (including exploratory procedures, e.g., arthroscopy)?

YES ☐ or NO ☐

If Yes, please elaborate ____

____

3. Do your knees ever "give out" or "lock" on you?

YES ☐ or NO ☐

If Yes, please elaborate ____

____

4. Do your knees ever bother you going up and down stairs?

YES ☐ or NO ☐

If Yes, please elaborate ____

____

5. Have either of your knees ever been diagnosed as arthritic by a physician?

YES ☐ or NO ☐

If Yes, please elaborate ____

____

6. Have you ever been diagnosed as having high blood pressure?

YES ☐ or NO ☐

If Yes, please elaborate ____

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