THE OPTIMUM NUMBER OF REPETITIONS TO BE USED WITH ISOKINETIC TRAINING PROGRAMS

A Thesis Presented
to
The Graduate Faculty
University of Wisconsin-La Crosse

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

---

by
Stephen Rodney Bendle
May, 1985

BENDLE, Stephen Rodney. The optimal number of repetitions to be used with isokinetic training. M.S. in Adult Fitness - Cardiac Rehabilitation, 1985, 103pp. (K.L.Wood)

The purpose of this study was to determine the optimal number of repetitions necessary to obtain maximal effectiveness for isokinetic training. 16 males & 23 females from the University of Wisconsin - La Crosse & the Cybex Center in La Crosse were randomly assigned to training groups of varying reps in an attempt to investigate this problem. The groups were; Group 1) Control; Group 2) 3x5 reps; Group 3) 3x10 reps; Group 4) 3x15 reps; Group 5) 3x 20reps. All experimental Ss trained with full range isokinetic knee flexions and knee extensions 3/wk for 6 wk at 180 degrees/sec. The control group maintained their normal daily activities. All Ss had their knee flexors and knee extensors pre and post tested on a Cybex II dynamometer at 60, 120,180,240 & 300 degrees/sec for measures of peak torque, peak torque to body weight ratios and average power. A 30 repetition endurance test at 180 degrees/sec also measured total work and endurance ratios. A mixed design ANOVA and post-hoc Scheffe tests identified a wide range of sig. ($p<0.05$) improvements. The most important patterns were the sig. improvement of the 5 and 10 rep. groups in the strength measures, and the 15 and 20 rep. groups in the endurance parameters. Overall, the 10 rep. group provided the most consistent improvements in all measures. That group improved in nearly 60%, of measures. It was concluded that isokinetic training is repetition specific.

UNIVERSITY OF WISCONSIN - LA CROSSE
College of Health, Physical Education and Recreation
La Crosse, Wisconsin 54601

Candidate: Stephen Bendle

We recommend acceptance of this thesis in partial fulfillment of this candidate's requirements for the degree:

Masters of Science - Adult Fitness and Cardiac Rehabilitation

The candidate has completed his oral report.

Kimberly Wood — 6-10-85
Thesis Committee Chairperson — Date

Sandra Ryan — 5/24/85
Thesis Committee Member — Date

Mark J. Rowinski — 6/10/85
Thesis Committee Member — Date

George J Davies, PT — 6/11/85
Thesis Committee Member — Date

This thesis is approved for the College of Health, Physical Education and Recreation.

John C. Mitchem — June 12, 1985
Dean, College of Health, Physical Education and Recreation — Date

Howard C Rose — JUNE 17, 1985
Dean of Graduate Studies — Date

ACKNOWLEDGEMENTS

I would like to thank all the participants in this study for their time and cooperation. I'd also like to thank the committee members, George Davies, Mark Rowinski and Sandra Price for their time and suggestions. A special thanks to my chairperson Kim Wood for her help and guidance, and to my parents. A final note of gratitude to my wife Shirley for her sacrifice, patience and support.

TABLE OF CONTENTS

LIST OF FIGURES

FIGURE Page

LIST OF TABLES

TABLE Page

CHAPTER I

INTRODUCTION

Isokinetic exercise has developed into the most scientifically advanced method of strength training at present. It is widely used in rehabilitation clinics in the restoration of muscle strength after injury or disuse (Davies, 1984; Lamb, 1978). In the area of sports training, isokinetics have become very popular for a number of reasons. The results afforded to isokinetics are convincing (Counsilman, 1976) and the ability to imitate functional velocities and movements have proven beneficial (Halling & Dooley, 1979).

As with many other methods of resistance training, there are many factors that may determine the success of the program. These include training load, frequency, duration, speed, and rest periods. Unfortunately, there are very few universally accepted training programs available for any training method. This is definitely the case in the field of isokinetics. Research has provided many suggestions about combining training velocities with repetitions and frequencies, however, as many questions as answers have been raised. Hopefully, as research continues, more substantial information will emerge and help establih more acceptable training programs.

The number of repetitions used to obtain maximal training gains is one area which has, thus far, failed to attract adequate attention from researchers. However, this is a vital factor in the consideration of training protocols. The current literature indicates that strength, power, and endurance gains may be achieved at a wide range of training velocities. Therefore, the number of repetitions that are performed may determine the total amount of work that is accomplished by the muscle. This is very important because muscular effort is the key to muscular development (Westcott, 1984), and thus will affect training gains.

Therefore, this study was an attempt to clarify and provide suggestions as to the adoption of an optimal number of repetitions to be used in strength, power, and endurance isokinetic training.

Need for the Study

The optimal number of repetitions that should be used in any resistance training program is an important factor. Unfortunately, in the field of isokinetic training, research is lacking in this area. Thus, in the areas of sports training and injury rehabilitation, an important aspect of the training program is not based on substantial scientific evidence. Therefore, there is a need to determine what number of repetitions should be incorporated into an isokinetic training program to elicit the best results.

Hypotheses

The null hypotheses to be tested in this study were; when training the quadriceps and hamstrings isokinetically at 180 degrees per second: 1) there are no significant differences in measures of strength, power, and endurance between using 5, 10, 15, or 20 repetitions. 2) There are no significant improvements in strength, power or endurance in groups performing 5,10,15, or 20 isokinetic repetitions after 6 weeks of training.

The significance level was established at 0.05 to accept or reject these hypotheses.

Assumptions

The following assumptions governed this study:

a) All subjects gave a maximal effort during the testing and training sessions.

b) The Cybex II recordings were valid and reliable (Barbee, 1984).

c) Each subject refrained from any other specific exercise for the quadriceps and hamstrings beyond normal

Delimitations

The following were delimitations of the study:

a) All subjects were healthy, uninjured, and untrained as determined by information submitted by the subject (Appendix A).

b) Only males and females aged between 18-45 years of age were used in the study.

c) All training was performed at an angular velocity of 180 degrees per second (deg/sec).

d) The training program lasted 6 weeks.

e) Training was restricted to the quadriceps and hamstrings of the non-dominant leg only, while testing assessed both legs.

Limitations

The following were limitations of the study:

a) All subjects were volunteers.

b) The motivation and compliance of the subjects could not be uniformly controlled throughout the study.

Definition of Terms

The following terms have been defined to clarify their use in this study.

Strength - The ability to move a resistance or resist a force (Edington & Edgerton, 1976).

Power - Work performed per unit of time (Lamb, 1976).

Endurance - The ability to persist in performing some physical activity (Lamb, 1976).

The following terms are used in conjunction with the Cybex II system and the Cybex Data Reduction Computer (CDRC). Most of these are measures of strength, power, or endurance. The definitions are largely provided by Davies (1984). An example of the measurements, as recorded by the CDRC, is provided in Appendix B.

Torque - A measure of angular force, expressed in foot-pounds.

Peak Torque - The single highest torque value in the range of motion of the joint. The angle of occurrence was also recorded by the CDRC.

Peak Torque to Body Weight Ratio - The percentage of peak torque to body weight.

Range of Motion (ROM) - The CDRC measured the range of motion of the joint angle in degrees.

Average Power - The total work divided by the time taken to perform the work. This is expressed in watts.

Total Work - The total volume of work under the torque curve with each repetition. This measure can also be calculated for the entire length of the test.

Endurance Ratio - Comparison of the work done in a pre-selected number of repetitions at the beginning and end of the test. This is expressed as a percentage.

Pre-determined Repetition Bout Endurance Test - A test of endurance where the subject performs a pre-determined number of repetitions while the CDRC calculates the total work.

CHAPTER II

REVIEW OF LITERATURE

This review will attempt to outline the position which isokinetics presently occupies in the field of resistance training. The fundamental differences between isokinetics and other resistance training methods will be discussed. The present status of isokinetic training will also be outlined in terms of research conducted which attempts to determine the best training protocols.

Types of Resistance Training

Resistance training has developed into a science over recent years. Its importance has especially grown in the fields of sports training and injury rehabilitation. Presently, there are three predominant methods of resistance training.

Isometric Exercise

The term isometric is derived from the Latin meanings, same (iso) and length (metric). In other words, an isometric contraction is performed at zero velocity with no visible change in the length of the muscle. The muscle does not noticeably change in length because the external resistance is greater than the maximal tension the muscle is able to generate. Therefore, the resistance to the muscle will vary with the force applied. This is also referred to as a static contraction.

Isometric exercise has become popular in recent years because of the simplicity associated with this type of training. No equipment is necessary and the exercises are very time efficient. It has also been successfully used in the rehabilitation of sports injuries (Davies, 1984). Several training programs are available, however, they vary greatly in design.

The major disadvantage associated with isometrics is that strength gains are fairly specific to the joint angle that is trained (Davies, 1984; Mathews & Fox, 1976). The strength gains will decrease as the joint angle deviates from the specifically trained angle (Edington & Edgerton, 1976). A major contraindication to using isometrics is in the case of the post-coronary patient. The reason is primarily due to the valsalva maneuver associated with this type of exercise. The problem arises when the subject attempts a forced expiration against a closed glottis (windpipe). This will increase the intrathoracic pressure and subsequently raise systolic and diastolic blood pressures (deVries, 1980; Edington & Edgerton, 1976; Mathews & Fox, 1976).

Isotonic Exercise

Isotonic exercise is the most familiar type of strength training. An isotonic contraction is one in which the muscle contracts while moving a resistance. The muscle tension will vary throughout the full range of motion (ROM). Isotonic contractions can be divided into 2 types. Concentric contractions are the most familiar. These involve a shortening of muscle fibers during the contraction. This can be seen in Figure 1(a) when the arm lifts a load in this manner. The load is lifted by a concentric contraction of the bicep brachii. Eccentric contractions involve the lengthening of a muscle as the muscle fibers contract. The direction of the force generated is opposite to the displacement direction. Figure 1(b) is an example of an eccentric contraction. As the load is lowered, the biceps

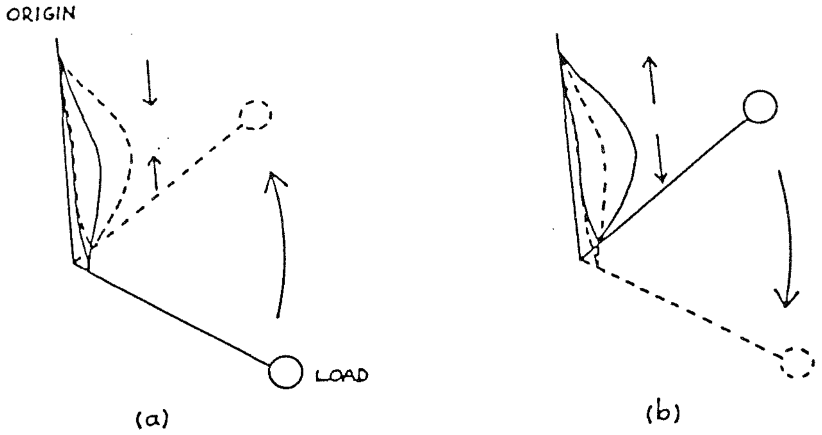


Figure 1(a) and (b). Diagrams showing concentric and eccentric contractions of the bicep brachii.

brachii is contracting eccentrically. As can be seen by this diagram, eccentric contractions work primarily against gravity. It has been shown that more muscle tension is developed during eccentric exercise than any other type of muscle loading (Figure 2). Eccentric training is often used

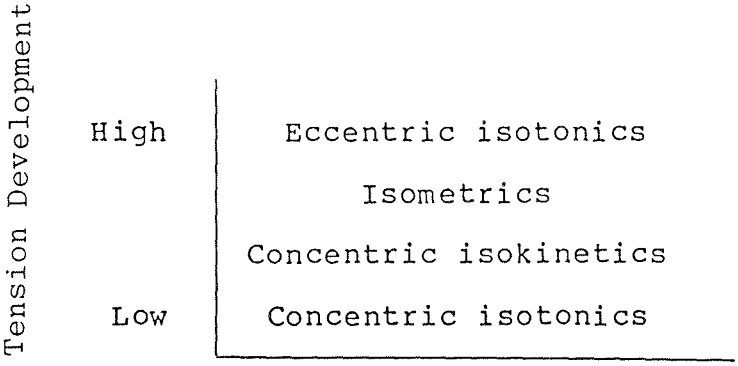


Figure 2. Comparison of tension developing capacities of various muscular contractions. From A compendium of isokinetics in clinical useage: Workshop and clinical notes (p.4), by Davies, G.J., 1984. La Crosse:S&S.

in the early stages of muscle rehabilitation, however, it has been associated with increased residual muscle soreness (Atha, 1982; Davies, 1984).

Isotonic training methods can also be classified as <u>constant</u> or <u>variable</u> (Davies, 1984). Constant resistance exercise uses a resistance that is constant throughout the ROM. An example of this is shown in Figure 1(a). Variable resistance training is common among most commercially available training equipment, eg: Eagle *, Nautilus **, and Universal ***. These machines attempt to vary the training resistance by the use of cams and levers. The design of the cam or lever aims to replicate the joint torque angles for the particular muscle being trained. The ability to successfully achieve this aim is presently under question.

Isotonic exercise has been the subject of many studies, most of them using different training protocols. Therefore, a wealth of information is available on training methods and programs.

Isokinetic Exercise

Isokinetic exercise is a relatively new concept in strength training. The origin of isokinetics lies in 1965 when Perrine designed the first Cybex device. In the first

---

* Cybex, Ronkonkoma, New York.

** Nautilus, DeLand, Florida.

*** Universal, Cedar Rapids, Iowa

published study on isokinetics, Hislop and Perrine (1967) introduced this method of training as an alternative to the established methods of isometric and isotonic training. They suggested that "the unique factor in the concept of isokinetic exercise is the control of the speed of muscular performance" (Hislop & Perrine, 1967, p.116).

During an isokinetic contraction, the tension developed by the muscle as it shortens can be maximal at all joint angles throughout the ROM. This may only be accomplished through specially designed equipment which changes its internal mechanical resistance in proportion to the changes in the force applied to it by the subject. Therefore, isokinetic training involves a fixed speed of movement with a varying resistance that is totally accommodating to the force applied by the individual throughout the ROM. This type of training is frequently referred to as Accommodating Resistance exercise.

The major advantage of isokinetics lies in the accommodating resistance factor. Davies (1984) points out that the torque developed by a joint as it goes through the ROM varies due to the length-tension ratio changes within a muscle group. Biomechanical leverage changes also occur. Isokinetics accommodate these changes. This can be seen in Figure 3.

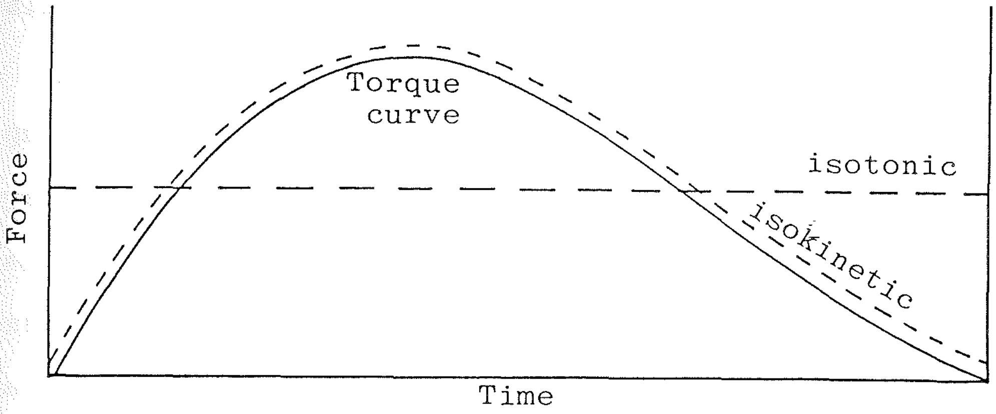


Figure 3. Comparison of isotonic and isokinetic muscular contractions in relation to a normal torque curve.

Other advantages afforded to isokinetics have been identified. Changes in biomechanical leverage and muscle length-tension ratios are accomodated, while isokinetics also allows for fatigue and pain. This is possible because the resistance to the muscle is always in proportion to the force applied. Therefore, as the muscle fatigues, the force and resistance decrease. Isokinetics have also been reported to cause less injury and residual soreness than other training methods (Jurgens, 1978; Lamb, 1976). Clinical usage also shows a decrease in joint compression forces when compared to other methods. Furthermore, the use of isokinetics in sports training has increased because of the ability to more clearly approximate performance speeds (Halling & Dooley, 1979).

It is thought that isokinetic training has displayed significant increases in strength primarily due to the physiological basis of the specific type of muscular contraction involved. Since the muscle is contracting maximally throughout the ROM, it seems reasonable to assume that maximum physiological changes will occur. Counsilman (1976) says that isokinetics permit optimal strength building stimulus throughout the ROM.

Isokinetics Compared to Other Resistance Training Methods

With the introduction of isokinetic training came the inevitable comparison with other training modalities. One of the first investigations was by Moffroid, Whipple, Hofkosh, Lowman, and Thistle in 1969. They trained 60 adults in one of three methods. Group 1 performed 10 isometric contractions at 90 and 45 degrees. Group 2 trained isotonically using wall pulleys, doing 3 sets of 10 repetitions, with the last set at 10RM. Group 3 did 30 repetitions at the testing speed of 22.5 deg/sec. After 4 weeks of training, the isokinetic group was found to have a significantly higher work output than the other groups.

Pipes and Wilmore (1975)(1) compared slow and fast isokinetics with isotonic training. Their results indicated that isokinetic training was superior to isotonic training for increasing strength and motor performance. Various tests were measured and, in the majority of cases, the isokinetic groups, especially the fast speed group, displayed significantly greater improvements than the isotonic group.

According to Gondola (1976), there were no significant differences between isometric, isotonic, and isokinetic training in 2 weeks of training after the onset of disuse atrophy in the knee extensors and flexors. However, the short time span covered by this study may have limited the implications of these results. The problem of satisfactorily measuring the effect of different training techniques was shown by Smith and Melton (1981). They found that an isotonic group improved significantly more than an isokinetic group, but only when measured isotonically. Conversely, the isokinetic group displayed greater improvement in tasks that duplicated their training speeds.

Grimby, Gustafsson, Peterson, and Remstrom (1980) compared 30 people who trained either isokinetically (42 deg/sec.), isotonically, or with a program of dynamic and static exercises. The authors found that all groups improved their strength when tested isometrically and at 30, 42, and 100 deg/sec. The isokinetic group was significantly stronger when tested isometrically. This was the only significant difference between the groups. The authors suggested that the very slow training speed of the isokinetic group, which was designed to be similar to the isotonic group, may have been responsible for there not being greater improvement.

One study that showed an overwhelming superiority of isokinetic training was by Saar, Ariel, Penny, and Saar (1982). They compared isokinetic exercise, variable resistance (isotonic), and free weights (isotonic) with a control group over 12 weeks. The subjects were tested on a number of variables, including isokinetic, isotonic, and motor performance tests. Anthropometric measurements were also taken. In each variable, the isokinetic group displayed significantly greater improvements than any other group. Therefore, the authors concluded that isokinetic exercise improved speed, strength, and other human performance parameters at a faster rate than any other modality.

Meadors, Crews, and Adeyanju (1983) found quite different results to Saar et al. (1982). They studied 27 females over an 8 week period. The subjects were divided into an isokinetic and 2 isotonic groups. Testing showed that no group improved significantly more than another. The authors felt that 8 weeks may be too brief to elicit major training changes. This was based on a similar conclusion by Van Oteghan (1975). However, it may be likely that because the testing in this study was done on isotonic machines, the isotonic group was favored by the specificity principle.

Shields, Beckwith, and Kurland (1985) compared an isokinetic training group with an isotonic and a control group. The 53 female subjects were measured isokinetically, isometrically, and tested for endurance and vertical jump capacity. Both training groups improved strength and performance but neither had a significant advantage. The authors concluded that comparison of groups was difficult because of the different training methods and equipment used.

Blattner and Noble (1979) compared isokinetic training with plyometric training. One group trained isokinetically (1.47 feet/second) for 8 weeks . The other group did 3 sets of 10 depth jumps with added resistance. Results showed that both groups increased their vertical jumping capacity, but neither was significantly better than the other.

In a comparison of a different kind, Halbach and Strauss (1980) compared isokinetic training with Electrical Muscle Stimulation. The investigation was limited to only 6 people. Three subjects trained isokinetically at fast speeds (150 - 270 deg/sec). The others had their quadriceps electrically stimulated. When re-tested at 120 deg/sec, the isokinetic group had clearly greater strength increases. Nobbs and Rhode (1984) conducted a similar investigation, but were unable to elicit significant differences between groups. There were slight differences in the velocities and the degree of electrical stimulation between these two studies and it seems further investigation is required in this area.

Evidence is available that substantiates the use of all present strength training methodsin terms of strength improvements. However, direct comparison of these methods is difficult because of the varying research designs and the inherent problem of independently assessing the strength gains of the different techniques. The principle of training specificity inevitably favors the group that trains with the testing device. Therefore, the evaluation of strength gains must be carefully interpreted in terms of the type of equipment used for training and testing (Shields et al., 1985). Mathews and Fox (1976) suggest the lack of well designed studies as the reason for there being no conclusive evidence as to which is the superior training method. However, they feel the scientific principles of isokinetics to be the most beneficial type of strength training. Table 1 presents some aspects of the various training methods, their benefits, and their disadvantages.

Table 1

Summary of Advantages of Isokinetic, Isotonic, and Isometric Training Methods. A Rating of 1 is Superior; 2 is Intermediate; and 3 is Inferior.

	Type of Training		
Criterion	Isokinetic	Isotonic	Isometric
Rate of Strength Gain	1	1	2
Strength Gain Throughout Range of Motion	Excellent	Good	Poor
Time per Training Session	2	3	1
Expense	3	2	1
Ease of Performance	2	3	1
Ease of Progress Assessment	Expensive Equipment Required	Excellent	Dynamometer Required
Adaptability to Specific Movement	1	2	3
Probability of Soreness	Little Soreness	Much Soreness	Little Soreness
Probability of Musculo-skeletal Injury	Slight	Moderate	Slight
Cardiac Risk	Some	Slight	Moderate
Skill Improvement	Some	Some	None

From <u>Physiology of exercise: responses and adaptations</u> (p.280), by Lamb, D.R., 1984. New York: Mac Millan.

Variable Components of Isokinetic Training

Unfortunately, there appear to be no universally accepted protocols for any of the three discussed resistance training methods. Many models have been theorized, but very few are scientifically based. The major problem lies in the many factors involved with resistance training. For example, training load, frequency, duration, speed, rest periods, motivation, and repetitions are all variables which must be considered when establishing training programs.

An examination of the literature shows a wide range of opinions and recommended protocols that can be used to obtain significant training results with isokinetic training. Most investigators have studied the effects of varying training velocities on strength, power, and endurance. This is probably because the controlled velocity is one of the unique aspects of isokinetic exercise. Being able to determine the optimal training velocity would be a major advancement in this field. Unfortunately, little research has been reported on the effects of different repetitions on training improvements. Magee and Currier (1984) are the only investigators to specifically study this aspect. Therefore, the following review is of literature pertaining to general studies using isokinetics for training the quadriceps and hamstrings.

The training methods used or suggested by the following studies have been condensed in Appendix C to facilitate the comprehension and comparison of the studies. The conclusions and implications of each study are presented in this review with reference to the information provided in that Appendix.

Fast versus Slow Isokinetic Training

The discussion concerning the benefits and superiority of fast versus slow velocity training has attracted the greatest amount of attention from investigators. A wide range of conclusions have been presented but, unfortunately, results vary with research designs. The most consistant finding is the high degree of velocity specific improvements that are associated with isokinetic training (Caizzio, Perrine, & Edgerton, 1980; Chaloupka, Fasano, Scibilia, & Philippi, 1985; Coyle, Feiring, Rotkis, Cote, Roby, Lee, & Wilmore, 1981; Jenkins, Thackaberry & Killan, 1984; Moffroid & Whipple, 1970; Quillen, 1981; Shermen, Plyley, Vogelsang, Costill, & Habansky, 1981).

Davies (1984) catergorizes velocities as follows:

0-60 deg/sec - Slow
60-180 deg/sec - Intermediate
180-300 deg/sec - Fast

Unfortunately, some early studies, such as by Moffroid and Whipple (1970), termed speeds of 108 deg/sec as fast. According to Davies' classification, such velocities are only intermediate. Discrepancies such as this lead to some difficulties in comparing investigations. Nevertheless, many researchers have attempted to clarify this question.

In 1970, Moffroid and Whipple were the first to evaluate the effects of different training speeds on muscular force and muscular endurance. Two groups (n = 30) trained at either 36 deg/sec, or 108 deg/sec, for 6 weeks. Post-test results showed that the slow group increased strength at speeds up to the training velocity and only slight gains at faster speeds. The faster group increased at all velocities. This group also displayed larger improvements in endurance than the slow group. These findings supported the authors' initial contention that low power exercise increases myofibrillar components of the muscle, thus directly affecting strength gains. Conversely, high power training increases the sarcoplasmic components of the muscle, therefore influencing endurance. The conclusion that slow speed gains are specific while fast speed gains occur at all velocities, has formed the basis of most isokinetic training to date. Many studies since have attempted to verify these findings.

In 1975, Van Oteghan compared fast and slow isokinetic training to see the effect on strength and vertical jump capacity. The study did not use a conventional isokinetic dynamometer. However, the training was done in a way that it took either 2 or 4 seconds to complete one isokinetic leg press. Although both isokinetic groups increased their vertical jump significantly, neither was significantly superior. When measured for strength, only the slow speed group improved significantly more than the control group. The author suggested that 8 weeks may not be long enough to elicit significant strength changes with fast speed training. However, studies since Van Oteghan's have shown significant increases in equal or shorter training periods.

The next major study comparing fast and slow training velocities was by Pipes and Wilmore (1975). They dealt with differences in strength, body composition, anthropometrics, and motor performance in four different training groups. The groups were: 1) Isotonic, 2) Isokinetic fast speed (130 deg/sec), 3) Isokinetic slow speed (24 o/sec.), and 4) Control. The results of the study showed that when tested isometrically, both isokinetic groups increased in strength significantly more than the other groups. When tested for isotonic strength, each training group increased significantly, with the fast isokinetic group improving more than the isotonic group in some tests. Isokinetic testing at slow speeds showed that only the isokinetic groups improved. The results were similar when fast velocity testing was used, however, the fast group improved significantly more than the slow group. The authors concluded that while the isokinetic fast speed group exhibited its greatest improvements with fast speed tests, it was found to be more effective in inducing strength changes than either isotonic or slow speed isokinetic training. Similar to Moffroid et al. (1969), they suggested that the superiority of the isokinetic groups was related to the uniqueness of the isokinetic muscle contraction.

In a study reported by Davies (1977), 130 students were measured to investigate the combination of speed and repetitions on strength improvements. Different groups trained with either 5, 10, or 15 repetitions at speeds of 1, 2.5, or 4 seconds per repetition. After 9 weeks, the only significant difference between the groups was between those who trained at 4 seconds per repetition and the other groups, when tested at 7 seconds per repetition. No differences occurred when the groups were tested at either .62 or 1.12 seconds per repetition. Therefore, it was suggested that slow velocity training was just as effective for improving fast speed strength as was fast speed training.

Caizzio and associates (1980) studied the in-vivo relationship between velocity and torque at different speeds. Seventeen subjects trained at either slow (96 deg/sec) or fast (240 deg/sec) velocities for 4 weeks. They were compared to a control group. Results showed that the slow group increased by 14.7%, at 0 deg/sec, but only 0.5%, at 288 deg/sec The fast group showed a similar but opposite trend. This indicated more specific adaptations to the training speeds than those shown by Moffroid and Whipple (1970).

Carr, Conlee, and Fisher (1981) used a similar training design as Lesmes, Costill, Coyle, and Fink (1978). Ten people trained one leg at a slow velocity (48 deg/sec) and the other leg at a fast speed (192 deg/sec). The training was equated so that the work outputs were similar. After a 9 week training period, it was found that strength had increased significantly in both legs when tested at speeds between 12-264 deg/sec. The improvements varied from between 15-20% at the slow speeds, to 40-45% at the faster speeds. Endurance also improved in both groups. The authors concluded that strength and endurance may be more related to the total amount of work performed than the training speed. This was an interesting conclusion in that it took the emphasis away from training velocities and introduced another factor that may play an important role in determining training protocols. It is this work factor that the number of repetitions may govern and therefore the importance of the present investigation is reinforced.

Coyle and co-workers (1981) also investigated the effect of training at different velocities. They trained 22 males in one of four different ways. Group 1 acted as a placebo. They had their quadriceps electrically stimulated to produce a contraction of only 3% of their maximal voluntary contraction. Group 2 performed 5 sets of 6 repetitions at 60 deg/sec. Group 3 trained with 5 sets of 12 repetitions at 300 deg/sec. The final group combined the 2 isokinetic methods by doing 2 or 3 sets of both the fast and slow training loads. After 6 weeks of training, the placebo group had only improved isometrically. The slow velocity group increased their peak torque by 20, 32, and 9%, when tested at 60, 180, and 300 deg/sec, respectively, The fast group improved more consistently, by 15 - 24%, at all velocities. The mixed group also improved at all velocities, but not to the extent of the fast group. These results were similar to Moffroid and Whipple (1970) and the authors concluded that fast speed training may improve strength throughout a wide range of velocities.

Smith and Melton (1981) also used fast (180 - 300 deg/sec) and slow (30 - 90 deg/sec) isokinetics in a comparison with Nautilus Variable Resistance machines. After 6 weeks of training, the isokinetic groups displayed significantly greater increases in strength than the variable resistance group. The fast group improved at slow speeds, but the largest improvement was at the faster speeds. The slow group improved in strength at both slow and fast speeds. This was surprising considering Moffroid and Whipple (1970), Pipes and Wilmore (1975), and Caizzio et al. (1980) had all shown that slow speed gains had been restricted to slow velocities. These authors suggested that the training speed selected should be specific to the need of the individual. Therefore, in a rehabilitation environment, a wide spectrum of training velocities is best recommended.

Adeyanju, Crews, and Meandors (1983) trained two groups of females for 7 weeks to further investigate the effect of velocity on strength, power, and endurance. The slow group trained at 30 deg/sec, and the other group at 180 deg/sec. Both groups did 3 sets of 20 seconds. The results showed that in the knee extensors both groups increased in peak torque and endurance when tested at both fast and slow velocities. However, the fast group improved significantly more in both.

Kanehisa and Miyashita (1983) trained 21 males for 8 weeks. They were one of the few studies to look at a wider range of training speeds. They had groups training at 60, 180, and 300 deg/sec, doing 10, 30, and 50 repetitions respectively. This meant that all groups trained for approximately 40 seconds per workout. It also represented slow, intermediate, and fast velocities. The slow group showed significant increases at all speeds, however, the percentage improvement decreased as the testing speed increased. The intermediate group showed similar gains at all test speeds, while the fast group improved only at the faster testing speeds. This strengthened the speed specificity theory, but indicated that an intermediate training velocity may be best for general improvement.

In 1984, Jenkins, Thackaberry, and Killan further investigated the concept of speed specific training changes. They trained 24 people for 6 weeks with 1 set of 15 at either 240 deg/sec, or 60 deg/sec. Their results, significant at the .01 level,showed that the slow group had gained strength at 60 and 180 deg/sec. The fast group improved only at 240 and 300 deg/sec. This supported other studies that training was specific to training speed. However, at the .05 level of significance, the fast group also improved at 30, 60, and 180 deg/sec. The slow group improved at 240 deg/sec. This meant that the training effect was much wider than first indicated. The authors expressed interest as to whether earlier studies may have shown different results if their level of significance had been expanded.

Vitti (1984) trained 30 males in one of three methods. Group 1 trained at intermediate speeds (60 - 150 deg/sec); Group 2, at fast speeds (210 - 300 deg/sec); and the other group used a combination of the slow and fast speeds. Results showed significant strength improvements in all groups, but no difference between the groups. The author suggested that 6 weeks of training may not be sufficient to extract different responses between groups. This was based on similar findings by Van Oteghan (1975). However, many investigators have shown improvements in similar training periods (Carr et al., 1981; Coyle et al., 1981; Lesmes et al., 1978; Moffroid et al., 1967; Pipes & Wilmore, 1975).

With results such as those presented by Moffroid and Whipple (1970) and Pipes and Wilmore (1975), some researchers attempted to apply these findings to the clinical environment. Costill, Fink, and Habansky (1977) studied 18 patients before and after menisectomy surgery. The patients were assigned to 1 of 2 rehabilitation groups. Both groups undertook a progressive strength training program, while one group supplemented this with 20 - 30 minutes of pedalling a stationary cycle. The strength training consisted of knee extensions with a weighted bar. After 6 weeks of training, all the patients had regained their knee extension strength when measured by a maximal lift of the weighted bar. However, when tested on an isokinetic leg press machine, the surgical limb was still approximately 20% weaker than the normal leg. This was a major indication that rehabilitation training is task specific and therefore patients should do fast and slow speed exercises with a variety of activities to ensure adequate recovery from knee surgery. Although this study did not specifically train isokinetically, it clearly showed the relationship of task and speed specificity. Rehabilitation programs presently in use incorporate multi-speed exercises. (Davies, 1984; Wright & McNeil, 1979).

The argument for slow velocity training has been recently outlined by Westcott (1984). Unfortunately, his explanations are not based on research evidence. Nevertheless, he contends that "slow weight training is both more productive in terms of improving muscle strength, and less destructive." (Westcott, 1984, p.42). This is based on a number of points. More muscle tension is produced because of a larger contraction force. This is supported by evidence that peak torque decreases as velocity increases. Additionally, because the firing rate of motor nerve impulses at slow speeds is not fast, the increased muscle force must be due to an increased recruitment of muscle fibers. Therefore, this produces a greater training response. Finally, less momentum is developed with slow training methods. An earlier review by Kearney (1980) advocated similar points. He suggested that isokinetic training should be done slow enough to allow significant force development. A velocity of 50 - 60 deg/sec, was suggested.

Although slow velocity training has been found to improve strength, it usually occurs only at the specific training speed. Slow velocities have also been found to increase compressive forces in the knee (Davies, 1984) and are not functional speeds for human activity. Therefore, slow velocities need to be supplemented by fast speeds to provide a complete rehabilitation or strength program.

Unfortunately, research is still inconclusive with respect to isokinetic training, in relation to velocity

(Vitti, 1984). The above discussion clearly shows diverse conclusions and differing opinions. The main contention arising from the literature is that isokinetic training strongly supports the specificity principle. Sale and McDougall (1981) offer a number of reasons why specificity plays such an important role in isokinetic training. Firstly, the movement pattern lends itself to skill acquisition. This seems to contribute greatly to any strength gains. Evidence shows that training is usually specific to the trained joint, joint angle, and joint velocity. This is primarily attributed to neurological changes. The second important factor is the actual training velocity. There is some evidence that fast velocities may have a larger overflow to slower velocities. However, this has not been shown consistently. Quillen (1981) provides sound reasoning that Velocity Spectrum Training (VST), which involves a multi-speed program, allows optimal neuromuscular response to isokinetic exercise. He suggests the following benefits of VST:

1) Allows activation of both aerobic and anaerobic systems, eg. both fast and slow twitch fibers.

2) Overcomes pain and apprehension by progression.

3) Adapts to biomechanical changes.

4) Closely approximates normal functional activity.

With these points in mind, it seems that a properly constructed strength or rehabilitation program should include both fast and slow training velocities (Sherman et al. 1981).

Repetitions

At present, there is little research that adequately determines the optimal number of repetitions that should be used with isokinetic training (Davies, 1984). Therefore, present training programs are based more on practical experience than scientific evidence. The available literature provides a number of suggestions. Pollock, Wilmore, and Fox (1984) recommend 3 sets of 5 - 7 repetitions based on existing isotonic programs. Jensen and Jensen (1978) suggest that 3 sets of 6 - 8 is best, however, they concede that any combination similar to this will produce similar results.

Among the studies done in this area, Lesmes and co-workers' (1978) research is the most comprehensive. Unfortunately, the study was limited to only 5 subjects and was primarily designed to investigate muscle fiber changes. Two training regimens were designed to emphasize either the ATP-PC or the glycolytic metabolic energy systems. This was achieved by each subject training one leg for 6 seconds and the other for 30 seconds, both at 180 deg/sec. This represented approximately 5 and 25 repetitions, respectively. Both methods increased strength significantly when tested at 0, 60, 120, and 180 deg/sec, however, no gains occurred at 240 and 300 deg/sec. An important finding was that there were no significant differences between the two training methods in terms of strength gains. One aspect not considered by these authors was the presence of any bi-lateral transfer of strength improvements. Although this area deserves more comprehensive discussion, it is a factor that may contaminate this type of training procedure.

Lesmes et al. also took anthropometric measurements but found no differences after the training. This led them to conclude that the adaptations were both muscular and neuro-muscular in origin. This has been supported by other sources (Coyle et al., 1981; Lamb, 1978; Mathew & Fox, 1976; Sale & MacDougall, 1981). With these results, the authors concluded that increases in peak torque, by 5 - 25%, can be obtained with short duration (6 second : 5 repetition) training.

Davies (1977) has also concluded that the frequency of contraction may not be as critical as the intensity of the contraction. In a study comparing 5, 10, and 15 repetitions performed at 3 different velocities, there was found to be no significant differences between the groups. Therefore, he concluded that velocity was more important than repetitions in training.

Magee and Currier (1984) also studied the implications of varying numbers of repetitions on strength improvements. The study group of 55 females were assigned to 6 groups which trained for 2 weeks with either 6, 8, 10, 12, 14, or 16 repetitions. all groups trained at 30 deg/sec. After the training, when re-tested, the authors found no significant differences between the groups, therefore concluding that any number of repetitions between 6 - 16 could be used to elicit similar improvements in muscle strength. Unfortunatley, the very slow training speed and the brief training period are not very functional elements in normal training. Therefore, the application of these findings to the rehabilitation environment may be limited.

Unfortunately, the few studies that have addressed the question of repetitions vary in design and each have a number of limiting factors. It appears obvious that more comprehensive research is required in this area of isokinetic training. Therefore, this study is undertaken in an effort to provide substantial information on the effect that repetitions have on isokinetic strength, power and endurance.

CHAPTER III

METHODOLOGY

To determine whether there is an optimal number of repetitions to be used with isokinetic training, the following methodology was used. This chapter was divided into the following sections: 1) Subject Selection, 2) Instrumentation, 3) Testing Procedures, 4) Training Procedures, and 5) Statistical Treatment of Data.

Subject Selection

Subjects in the study were volunteers from either the University of Wisconsin- La Crosse, or the Cybex Center USA in La Crosse. In total there were 39 participants in the study. Sixteen were males and 23 were females. All subjects were healthy, uninjured and reported no recent strength training to the lower extremeties. This information was obtained from subject information forms (Appendix A). All subjects were between 18 - 45 years of age. Table 2 shows the mean height, weight, and ages of the subjects.

The subjects were randomly assigned to one of 5 groups. The groups were: 1) Control (n = 8), 2) 5 repetitions (n = 8) , 3) 10 repetitions (n = 8), 4) 15 repetitions (n = 7), and 5) 20 repetitions (n = 8). Each subject was instructed in the procedures and signed an informed consent prior to testing (Appendix D).

Table 2

Means and standard deviations of heights, weights and ages of subjects.

Group	Height (in./SD)	Weight (lb./SD)	Age (yr./SD)
A	66 (4)	145 (29)	22 (2)
B	68 (3)	143 (28)	24 (7)
C	67 (3)	140 (10)	22 (3)
D	67 (5)	148 (29)	29 (5)
E	68 (4)	157 (43)	28 (7)

Instrumentation

The subjects were tested on a Cybex II dynamometer for measures of strength, power, and endurance in the quadriceps and hamstrings. The Cybex II was a loading device through which the torque produced by the joint movement was transmitted. The dynamometer moved at a pre-selected velocity. The Cybex II was linked to a dual channel recorder that recorded torque values and the range of motion of the joint (Appendix B). A Cybex Data Reduction Computer (CDRC) was also used in conjunction with the Cybex II. This allowed the measures of strength, power, and endurance to be calculated and recorded.

Both Cybex systems that were used for testing in this study were calibrated at regular intervals throughout the study. Calibration guidelines, as established by Cybex (1980), were followed (Appendix E).

Training was done on either the Cybex II or on a Cybex Orthotron KT2. Both of these machines use a similar mechanical device and thus were expected to produce similar results.

Testing Procedures

Testing was done at the Orthopaedic and Sports Physical Therapy Clinic in La Crosse and in the Physical Therapy Department at the University of Wisconsin - La Crosse. The guidelines established by Cybex (Cybex, 1983) for testing the knee flexors and extensors were used for this study (Appendix F).

The subjects were positioned with the shin pad proximal to the medial malleolus. The joint axis of the knee was aligned with the dynamometer axis and velcro stabilization straps were placed across the thigh, waist, and chest. (Figure 4). After the subject was positioned and stabilized, the Cybex checklist for testing was followed (Appendix G). Once this was completed, the testing instructions issued by the CDRC were followed (Appendix H).

As recommended by Davies (1984), Velocity Spectrum Testing was used in this study.

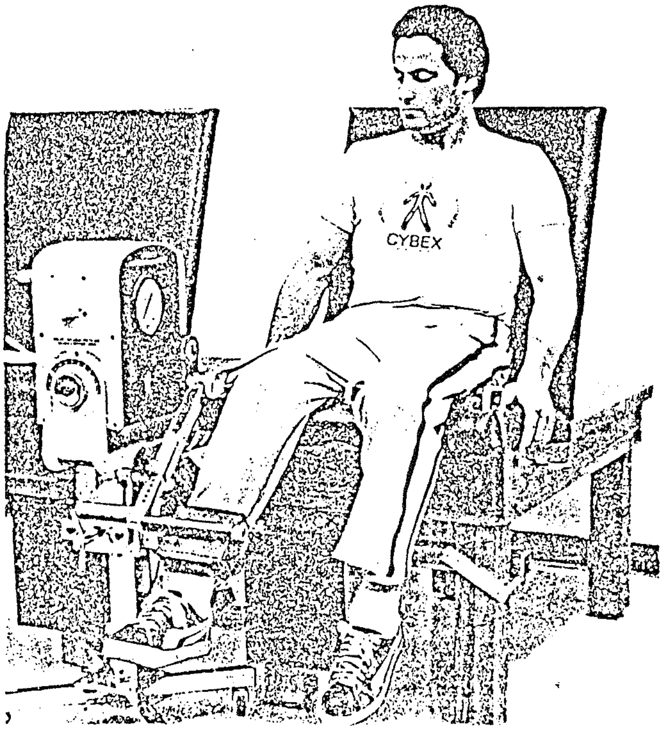


Figure 4. Patient positioning for testing. (A chest stabilization strap was also used). From Isolated joint testing and exercise (p. 69), by Cybex, 1983. New York:Cybex.

This involved testing the joint at a wide range of joint velocities. The speeds used were 60, 120, 180, 240, and 300 deg/sec.

Both limbs were independently tested in all subjects and the subjects were encouraged to give maximal efforts. Each subject was given 5 submaximal and 1 maximal trial at each velocity. This was to familiarize the subject with the machine and allow an adequate warm-up (Davies, 1984; Mawdsley, 1982). After the trials, each subject was asked to perform 5 maximal contractions. The computer calculated and recorded Peak Torque, Peak Torque to Body Weight Ratio and Average Power.

The subjects were also given a Pre-Determined Repetitions Bout Endurance Test. This was to test the muscular endurance of the quadriceps and hamstrings. In agreement with Davies' (1984) suggestion, 30 repetitions at 180 deg/sec was used as the testing protocol. The CDRC calculated and recorded measures of Total work and endurance ratios.

After the testing was completed, the subjects were assigned to one of the training groups and the training procedures were explained in conjunction with an information pamphlet given to each individual (Appendix I). The subjects had the opportunity to ask questions before leaving. Following a 6 week training period, all subjects were re-tested in a similar manner.

Training Procedures

Training was done on the quadriceps and hamstrings of the non-dominant leg only. Leg dominance was determined at the testing session by asking the subject to kick a ball. The leg used was determined as being the dominant leg.

All subjects were asked to continue their normal activities during the 6 week training period and to refrain from any other specific quadricep or hamstring training beyond the training regimen used in this study. Training was done 3 times per week and not on 3 consecutive days. This number of training sessions has been found to be just as effective as 5 times per week (Rozier & Schafer, 1980). The training program lasted 6 weeks. This time period most closely approximated the average time period associated with rehabilitative exercise (Davies, 1984; Halbach, 1983). The training speed of 180 deg/sec, was chosen because it is the velocity most commonly used in clinical rehabilitation (Davies, 1984). The subjects were randomly assigned to one of the following training groups:

Group 1.....Control

Group 2.....3 sets of 5 repetitions @ 180 deg/sec.

Group 3.....3 sets 0f 10 repetitions @ 180 deg/sec.

Group 4.....3 sets of 15 repetitions @ 180 deg/sec.

Group 5.....3 sets of 20 repetitions @ 180 deg/sec.

These repetitions were selected to achieve a wide range of training conditions. Lesmes et al. (1978) have suggested that 5 repetitions emphasizes the ATP-PC system, while 25 repetitions utilizes the glycolytic system. Magee and Currier (1984) trained groups using 6, 8, 10, 12, 14, and 16 repetitions and found no significant differences between them. Jensen and Jensen (1978) stated that subtle variations of any training protocol would produce similar results. Therefore the wide range of repetitions selected for this study should identify any differences between repetitions.

Training was done by the students on a Cybex II at the University of Wisconsin - La Crosse in the Physical Therapy Department or on an Orthtron KT2 at the Student Health Center. Members at the Cybex Center USA used a Cybex Orthotron KT2 at that facility. Because of the number of subjects and individual schedules involved, not all the workout sessions were superised by the author. However, the author was available throughout the training period to answer any questions.

Statistical Treatment of the Data

The statistical analysis of the data was by an analysis of variance and covariance with repeated measures for each of the strength, power, and endurance measurements. Post-hoc (Scheffe) analysis was done if significant differences were identified. A 0.05 level of significance was established to reject or accept the null hypothesis.

CHAPTER IV

RESULTS AND DISCUSSION

The purpose of this study was to determine if there was an optimal number of repetitions that should be used in isokinetic rehabilitative or conditioning programs. Slow-contractile velocities (strength), fast-contractile velocities (power), and power-endurance parameters were measured and compared between experimental groups after 6 weeks of isokinetic training This chapter includes the results of the peak torque, peak torque to body weight ratios, average power, and endurance measures. A discussion of the implications of the results is also included.

An analysis of variance and covariance with repeated measures was performed to determine if, 1) there were any significant differences between the groups, and 2) there were any significant improvements from pre to post tests. Post-hoc Sceffe tests were performed to identify any significant differences that were shown. In each parameter measured, the control group values were unchanged from pre to post test. This was to be expected as they were encouraged to continue heir normal daily activities. The analysis also showed no significant differences between the groups except in total work of the quadriceps. Many groups improved significantly with the training and these results will be discussed in this chapter.

Peak Torque

Peak torque values, means and standard deviations of the experimental and control groups for the pre and post tests are presented in Tables 3 and 4.

Pre and post-test results of the quadricep measurements show that there were no significant improvements by any group at 60 deg/sec. However, groups B (5 reps) and C (10 reps) were significantly stronger at all other testing speeds. Group E (20 reps) significantly improved at 120 and 180 deg/sec, and group D (15 reps) improved at 300 deg/sec. All values were within normal ranges (Wyatt, 1981).

The most obvious pattern of improvement was by the groups performing 5 and 10 repetitions. These groups improved in peak torque at most testing speeds, including those above the training speed. This confirmed findings by Carr et al. (1981), Davies (1977), Jenkins et al. (1984), Kanehisa and Miyashita, (1983), Sherman et al. (1981), and, Smith and Melton, (1981). Conversely, others, (Caizzio et al., 1980; Chaloupka et al., 1985; Lesmes et al., 1978; Moffroid and Whipple, 1970; and, Pipes and Wilmore, 1975) have found increases in peak torque only at and below the training velocity. However, the present study showed that

TABLE 3
Peak torque means and standard deviations for the pre and post tests of the quadriceps.

		Group A		B		C		D		E	
Velocity (o/sec.)		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
60	pre.	117.8	78	115.8	40	115.5	13	115.5	26	117.3	32
	post.	120.8	36	122.0	45	129.1	26	118.4	31	121.3	40
120	pre.	106.6	34	92.3	26	94.5	16	93.8	29	93.0	30
	post.	104.5	35	105.0*	38	108.7*	22	98.8	33	108.8*	37
180	pre.	83.1	34	74.7	20	76.2	16	77.8	27	80.3	31
	post.	87.8	39	87.1*	28	91.6*	21	85.5	30	95.3*	36
240	pre.	69.8	33	60.1	15	61.7	15	64.5	24	71.6	28
	post.	72.8	28	76.8*	31	75.7*	19	73.0	29	76.5	29
300	pre.	60.0	28	51.1	15	49.1	14	53.6	23	58.3	22
	post.	62.5	23	64.0*	27	57.8*	19	64.8*	28	66.5	24

* significant improvement ($P<0.05$) from pre to post test.

Table 4
Peak torque means and standard deviations for the pre and post tests of the hamstrings.

Velocity (o/sec.)		Group A		B		C		D		E	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
60	pre.	74.0	35	67.1	33	61.0	16	72.4	22	70.5	32
	post.	76.0	31	68.7	29	72.5*	18	75.0	27	80.8*	35
120	pre.	67.2	30	58.6	23	56.7	18	61.1	20	60.7	24
	post.	65.5	27	64.1	25	66.1*	17	68.1	23	75.0*	31
180	pre.	59.2	32	54.1	25	50.2	20	54.0	18	53.2	22
	post.	57.5	26	57.2	24	58.2*	16	60.8	25	62.8*	24
240	pre.	50.6	28	46.1	21	41.1	20	47.4	16	47.3	20
	post.	48.6	26	53.1	22	48.8	13	54.4	23	54.8	22
300	pre.	42.7	26	40.5	19	36.8	18	40.7	14	40.7	17
	post.	43.2	25	46.2	19	39.6	17	48.0	21	43.8	15

* significant improvement ($P<0.05$) from pre to post test.

transfer to slower velocities was not complete, in that there were no significant improvements by any group at 60 o/sec. In particular, group B differed dramatically from results presented by Lesme et al. (1978). They found that a similar training group improved at 60, 120 and 180 deg/sec, but not at 240 and 300 deg/sec. Results of testing the hamstrings for peak torque showed that only groups C and E significantly improved with training. Both these groups improved at and below the training velocity of 180 deg/sec. As mentioned earlier, there are other studies that support this particular pattern.

The differences in training responses between the hamstrings and the quadriceps is unexplained. One possible reason is that the distribution of muscle fiber types between the two muscle groups may be disimilar. However this seems unlikely to have affected the results of the study since the respective percentages of Type I and Type II muscle fibers vary dramatically between muscles and between individuals (Johnson, Polgar, Weightman, and Appleton, 1973). Another reason may be the effect of gravity on the training apparatus. The Cybex training machines used in this study create a gravitational disadvantage for knee extension and a gravitational advantage for knee flexion. Further investigation into this aspect is necessary.

The absence of significant improvement by group D, other than in the quadriceps at 300 deg/sec, is an interesting outcome. Jenkins et al. (1984) used 1 set of 15 repetitions at either 60 or 240 deg/sec in a training study over 6 weeks. They found significant results at a variety of testing velocities in both groups. However, one possible reason that the present study failed to duplicate these results may have been alluded to by Lesmes et al. (1978). They indicated that 5 repetitions at 180 deg/sec stimulated the ATP-PC metabolic system. Conversely, 25 repetitions relied primarily on glycolytic metabolism. It may be that 15 repetitions, at 180 deg/sec, is within a "grey" area of energy metabolism transfer, and thus, the training response may be affected.

Peak Torque to Body Weight Ratio

There is evidence that peak torque values are affected by age, sex, height, and weight (Watkins and Harris, 1983). Therefore, peak torque to body weight ratio is an important parameter to measure. Mean values and standard deviations of the groups for pre and post tests are presented in Tables 5 and 6.

The results show similar trends to the peak torque values. The only different results were in the quadriceps at 300 deg/sec, where group E improved significantly while group C did not. Additionally, group C improved significantly in hamstring values at 240 deg/sec. The

Table 5.
Peak torque to body weight ratio means and standard deviations for the pre and post tests of the quadriceps.

		Group A		B		C		D		E	
Velocity (o/sec.)		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
60	pre.	86.7	16	80.1	18	84.2	9	78.4	6	76.0	16
	post.	84.5	17	83.0	18	93.1	16	80.7	10	79.0	19
120	pre.	70.1	14	68.5	17	67.2	10	63.0	8	60.2	15
	post.	72.5	16	76.3*	21	78.2*	12	66.7	11	70.6*	17
180	pre.	57.1	13	56.2	17	54.1	9	51.7	8	52.2	16
	post.	61.0	14	64.3*	24	65.6*	12	57.4	11	61.5*	18
240	pre.	48.5	14	45.6	15	44.0	8	42.5	6	46.2	15
	post.	50.3	12	54.5*	19	54.2*	9	48.4	11	49.7	15
300	pre.	40.8	13	39.0	14	36.8	7	35.1	8	38.2	12
	post.	43.2	10	48.1*	18	41.6	10	42.0*	10	43.4*	13

* significant improvement ($P<0.05$) from pre to post test.

Table 6
Peak torque to body weight ratio means and standard deviations for the pre and post tests of the hamstrings.

Velocity (o/sec.)		Group A		B		C		D		E	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
60	pre.	50.1	12	45.1	15	43.2	9	48.8	8	43.8	9
	post.	51.8	12	50.5	14	52.0*	10	50.2	9	50.5*	10
120	pre.	45.8	11	43.3	16	40.0	11	41.0	8	38.5	8
	post.	44.1	12	48.7	18	47.3*	10	45.8	8	47.0*	8
180	pre.	40.0	14	40.0	18	35.2	12	36.0	6	34.0	9
	post.	39.3	12	43.7	19	41.6*	9	40.4	9	39.7*	8
240	pre.	32.3	16	37.7	25	29.0	12	31.7	5	30.1	9
	post.	33.1	14	39.3	18	36.0	6	36.1	8	34.8	10
300	pre.	27.3	13	31.7	14	26.0	11	27.1	5	26.2	8
	post.	28.6	13	34.3	15	28.2	11	31.5	8	28.0	4

* significant improvement (P<0.05) from pre to post test.

similarities to peak torque results is to be expected considering the close relationship between these parameters.

According to normative data (Davies, 1984), most quadricep pre-test values for this study were within normal ranges. Post-test values usually exceeded the normal values. Unfortunately, there is little data available in the literature that concerns training influences on peak torque to body weight ratios, Therefore, unless dramatic weight changes occur during the rehabilitation or conditioning period, this parameter may be interchanged with the peak torque to gauge training improvements. However, as a measure of evaluation, the two parameters should continue to be viewed independently.

Average Power

Power may be the most important aspect of physical performance (Kanehisa and Miyashita, 1983). Therefore average power was measured by the CDRC. Mean values and standard deviations, for the pre and post tests, are presented in Tables 7 and 8.

Quadricep results showed that only group C significantly improved average power values. The improvement occured at 120, 180, and 240 deg/sec. This indicated a physiological training overflow of 60 deg/sec either side of the training velocity. This supports similar findings by Sherman et al. (1981) and Jenkins et al. (1984).

Table 7.
Average power means and standard deviations for the pre and post tests of the quadriceps.

	Group	A		B		C		D		E	
Velocity (o/sec.)		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
60	pre.	119.4	43	109.7	40	106.8	22	118.1	40	113.6	33
	post.	114.5	41	107.8	43	115.7	24	117.5	32	102.6	30
120	pre.	195.3	78	176.6	55	177.0	38	185.5	76	177.2	52
	post.	201.4	80	193.6	76	208.5*	40	198.3	65	181.2	52
180	pre.	246.7	101	217.0	73	219.7	58	225.1	98	228.2	67
	post.	269.4	112	248.3	94	268.6*	62	257.1	93	247.3	69
240	pre.	276.4	128	231.7	73	241.0	70	250.8	108	273.3	86
	post.	305.4	134	264.3	123	298.3*	69	293.4	109	281.3	83
300	pre.	303.8	144	255.7	93	254.0	66	267.4	119	281.1	110
	post.	303.5	131	305.3	139	277.3	98	333.0	146	312.2	81

* significant improvement (P<0.05) from pre to post test.

Table 8
Average power means and standard deviations for the pre and post tests of the hamstrings.

		Group A		B		C		D		E	
Velocity (o/sec.)		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
60	pre.	75.5	40	64.1	34	61.1	25	79.5	37	75.7	29
	post.	71.7	33	61.2	27	71.5	21	91.7	38	65.3	25
120	pre.	133.1	67	115.0	54	110.8	51	130.5	66	130.6	56
	post.	134.0	61	136.8	61	134.5	44	156.1	52	126.8	52
180	pre.	175.4	93	149.1	77	146.1	78	164.8	87	166.1	71
	post.	179.8	80	161.3	76	180.5*	64	193.5	78	152.6	57
240	pre.	195.2	110	158.0	84	156.5	104	192.7	98	198.8	92
	post.	214.2	109	189.7	96	197.5	70	225.0	97	184.7	78
300	pre.	196.0	110	180.0	91	163.6	115	195.1	101	200.7	103
	post.	225.8	122	212.8	101	198.7	104	243.2*	122	190.7	86

* significant improvement (P<0.05) from pre to post test.

Hamstring values showed that group C improved significantly at 180 deg/sec. This was a specific response to the training velocity. Additionally, group D significantly improved at 300 deg/sec.

Kanehisa and Miyashita (1983) provide the only training data using average power. Values in the present study were consistently lower than those obtained by Kanehisa and Miyashita (1983). Differences in the subject populations probably account for this. Their results showed that a group training at 180 deg/sec, performing 30 repetitions, 6 times a week for 8 weeks, improved significantly at all testing velocities. The present study used a similar training protocol (group C), but only 3 times per week for 6 weeks. Although Parker (1981) suggests that power is the slowest of all parameters to respond to conditioning, perhaps, with further training, the improvement of group C in the present study may have been expanded to the wider ranges of the velocity spectrum. This pattern confirms the speed specificity principle, where the training response occurs initially at the training velocity and then overflows to other velocities.

Endurance

Muscular endurance is an important aspect of rehabilitation, because of its relationship to functional activities (Davies, 1984). Therefore, endurance was assessed by the CDRC, by calculating the total work performed by the muscle group during a pre-determined repetitions bout endurance test. Mean values and standard deviations for the pre and post tests are presented in Tables 9 and 10. Muscle endurance ratios were also calculated. These values are presented in Table 11 and 12.

Post testing of the quadriceps showed that total work improved significantly in groups C, D, and E. Further analysis showed that groups D and E improved significantly more than group C. In the hamstrings, group C was the only group to significantly increase their total work.

These results were similar to Adeyanju et al. (1983), who trained subjects at 180 deg/sec doing 3 x 20 seconds (15 repetitions). They found significant improvements in endurance in both the quadriceps and hamstrings. Moffroid and Whipple (1970) also found that a group training with 60 repetitions improved endurance more than a group performing 20 repetitions.

When comparing pre and post training values for endurance ratios, the quadricep values improved significantly in group B only. There were no significant improvements in hamstring values.

These results suggest that there is no relationship between endurance ratio and total work. There are no studies comparing these values, however, a relationship has been

Table 9

Total work means and standard deviations for the pre and post tests of the quadriceps

	PRE		POST	
Group	$\bar{X}$	SD	$\bar{X}$	SD
A	2385	1191	2388	1014
B	2068	547	2278	683
C	2119	434	2372*	395
D	2071	794	2521*+	990
E	2166	713	2616*+	866

* significant improvement ($P<0.05$) from pre to post test.

\+ a more significant improvement ($P<0.05$) than group A, B or C.

Table 10

Total work means and standard deviations for the pre and post tests of the hamstrings.

	PRE		POST	
	$\bar{X}$	SD	$\bar{X}$	SD
Group				
A	1683	834	1601	716
B	1502	502	1618	754
C	1368	534	1639*	500
D	1611	828	1813	810
E	1607	586	1659	614

* significant improvement ($P<0.05$) from pre to post test.

Table 11

Endurance ratio means and standard deviations for the pre and post tests of the quadriceps.

	PRE		POST	
	$\bar{X}$	SD	$\bar{X}$	SD
Group				
A	49.9	30	52.8	6
B	52.1	9	63.5*	13
C	52.1	7	54.0	7
D	49.8	7	57.0	7
E	60.0	12	64.1	7

* significant improvement ($P<0.05$) from pre to post test.

Table 12

Endurance ratio means and standard deviations for the pre and post tests of the hamstrings.

	PRE		POST	
	$\bar{X}$	SD	$\bar{X}$	SD
Group				
A	73.5	34	60.3	9
B	61.7	16	61.0	23
C	52.7	14	58.5	9
D	61.1	9	58.0	9
E	60.3	12	65.6	7

assumed. Further investigation should be undertaken to analyse this relationship.

The results of the endurance test indicate that an increased number of repetitions will increase endurance. This is to be expected because of the training specificity principle. Carr et al. (1981) suggests that endurance is related to the total work performed. Therefore, by increasing the training work, endurance should improve.

This study provided the first comprehensive investigation into the effect that repetitions have on isokinetic strength, power and endurance. The results supply some much needed information that can now be applied to rehabilitative and conditioning programs. Professionals can now prescribe isokinetic exercise with more confidence than they were able to previously. This study also makes available training data on the little investigated parameters of peak torque to body weight ratios, average power, total work, and endurance ratios.

CHAPTER V

SUMMARY & CONCLUSIONS

Summary

This study attempted to determine the optimal number of repetitions to be used with isokinetic exercise. Measurements of slow contractile and fast contractile velocities, as well as endurance, were taken on 39 volunteers, before and after a 6 week training period. Subjects trained on a Cybex dynamometer at 180 deg/sec, performing 3 sets of either 5, 10, 15 or 20 repetitions, 3 times per week, for 6 weeks.

Little research was available on the influence of repetitions on training responses. The majority of investigations into isokinetic exercise have dealt with training velocities. Of the studies completed, none had found significant differences between different repetition protocols.

The present study concentrated more on the influence of different repetitions than any previous study. The results of the study showed some patterns as to the optimal number of repetitions that should be used. The training group using 10 repetitions (group C) significantly improved in 60% of the measured values. This was nearly twice as often as any other group. Group C was also the only group to consistently improve at slow and fast contractile velocities, and endurance. Previous investigation has indicated that isokinetic exercise is primarily velocity specific (Caizzio et al., 1980; Chaloupka et al., 1985; Coyle et al., 1981; Jenkins et al., 1984; Moffroid & Whipple, 1970; Quillen, 1981; Sherman et al., 1981). The present study suggests that isokinetic exercise is also repetition specific. This is indicated by the response of the groups to the different testing protocols. Strength measurements were obtained from 5 maximal repetitions. Post training results showed that the groups using 5 and 10 repetitions improved at all testing velocities except 60 deg/sec. Additionally, endurance was measured with a 30 repetition test. The groups training with 15 and 20 repetitions were the ones to improve most significantly. These results identify some specific relationship between the testing and training protocols.

Another implication of the present study is the apparent difference in training responses of the quadriceps and hamstrings. This can be observed by the lack of conformity in the training responses of the two muscle groups used by the experimental groups. This is virtually unexplained and may be due to differences in muscle composition. Gravitational aspects of the training device may also affect the results.

An obvious, and expected, pattern of improvement was the differences in responses of the experimental groups to the measures of slow contractile velocities, fast contractile velocities, and endurance. Barnes (1980) suggests that there is little relationship between strength and endurance. This is mainly attributed to energy metabolism specificity. This information suggests that the number of repetitions used should be related to the desired physiological response.

The training velocity of 180 deg/sec is considered intermediate (Davies, 1984). Other studies that have used 180 o/sec., as a training velocity found that it improved performance at a wide range of velocities (Adeyanju et al. 1983; Kanehisa & Miyashita, 1983). A similar pattern has been found in the present study. Most investigators have suggested a wide range of velocities be incorporated into any isokinetic conditioning or rehabilitative program (Costill et al., 1981; Coyle et al., 1977; Quillen, 1981; Sherman et al., 1981). However, it seems that if only one velocity were to be used, 180 o/sec., may provide the widest range of significant results.

Based on the result of the present study, it seems that 3 sets of 10 repetitions, performed 3 times per week for 6 weeks, is sufficient to significantly improve measures of slow-contractile strength and fast-contractile power in normal subjects. This number of repetitions will provide wider and more consistent improvements than either 5, 15, or 20 repetitions. At least 3 sets of 10, 15, or 20 repetitions should be used to improve endurance. Using 3 sets of 15 or 20 repetitions will improve endurance significantly more than 10 repetitions.

Conclusions

Based on the results of this study, the following conclusions may be drawn;

- Ten repetitions appears to provide the widest range of significant improvements in isokinetic exercise.
- Isokinetic exercise is repetition specific. This is in addition to previous findings that isokinetic exercise is primarily velocity specific.
- An intermediate isokinetic velocity (180 deg/sec) may provide a significant increase in slow contractile strength, fast contractile power and endurance at a wide range of velocities.
- In measures of isokinetic strength, 5 or 10 repetitions provide significant improvements at a wide range of velocities.
- In measures of isokinetic endurance, 10, 15, or 20 repetitions provide significant improvements.
- In measures of isokinetic endurance, 15 or 20 repetitions provide more significant increases than a lower number of repetitions.

Recommendations

The findings of this study are confined by the limitations that were imposed. Therefore many aspects could be further investigated. The following are some recommendations for further study;

* The influence of different repetitions should be studied at a wider range of training velocities

* A similar investigation to the present study be undertaken under a more strictly controlled environment to verify the findings of the present study.

* Investigation should be undertaken to analyse the relationship between endurance ratios and total work in endurance tests.

FOOTNOTES

Letter to the Editor

Much to my professional embarrassment, it has become necessary for me to disassociate myself from the article: Pipes, Thomas V. and Jack H. Wilmore, "Isokinetic vs Isotonic Strength Training in Adult Men." *Med. Sci. Sports* 7:262-274, 1975. Mr. Pipes completed this study as a part of his thesis for a Master of Arts degree in Physical Education at the University of California, Davis. I served as the advisor for his thesis.

Shortly after the publication of this study, Dr. Richard A. Berger, from Temple University, wrote to me questioning our data. After several rounds of correspondence, I requested that Mr. Pipes send all of his data to Dr. Berger, which he subsequently did. Dr. Berger analyzed the data and found substantially different results. Dr. Berger returned the data cards to me in April, 1977, and I conducted an independent analysis of the data in September, 1977, and also found major inconsistencies with the original published data. I returned the data cards and Dr. Berger's and my analyses to Mr. Pipes in October, 1977. At that time, I requested that he conduct a total review and analysis of the data and publish the corrections as an addendum in *Medicine and Science in Sports*. I requested that he complete this by January 1, 1978, or that I would be forced to disassociate myself from the study. He has not responded to my correspondence and I have allowed him an additional 14 months in which to comply with my request.

Please accept my apologies for this most unfortunate incident. I must accept full responsibility for what has occurred.

Jack H. Wilmore, Ph.D.
University of Arizona
Tucson, AZ

References cited

Adeyanju, K., Crews, T.R., and Meadors, W.J. (1983). Effects of 2 speeds of isokinetic training on muscular strength, power, and endurance. *The Journal of Sports Medicine and Physical Fitness*, *23*(3), 352-357.

Atha, J. (1982). Stengthening muscle. In D.L.Miller (Ed.), *Exercise and sport sciences reviews Vol.9*. The Franklin Institute.

Barbee, J. (1984). Reliability of Cybex computer measures. *Physical Therapy*, *64*(5), 721.

Blattner, S.E. and Noble, L. (1979). Relative effects of isokinetic and plyometric training on vertical jumping performance. *Research Quarterly*, *50*(4), 583-588.

Caizzio, V.J., Perrine, J.J., and Edgerton, V.R. (1980). Alterations in the in-vivo force-velocity relationship. *Medicine and Science in Sports and Exercise*, *12*(2), 134, (Abstract).

Carr, L.S., Conlee, R.K., and Fisher, A.G. (1981). Effects of fast and slow isokinetic weight training on strength and endurance. *Medicine and Science in Sports*, *13*(2), 108, (Abstract).

Chaloupka, E.C., Fasano, T.J., Scibilia, G.J., and Phillipi, T.K. (1985). Reciprical effects of slow and fast speed isokinetic training in non-athletic college females. Submitted to the Journal of Orthopaedic and Sports Physical Therapy.

Costill, D.L., Fink, W.J., and Habansky, A.J. (1977). Muscle rehabilitation after knee surgery. *Physician and Sports Medicine*, *9*, 71-74.

Counsilman, J.E. (1976). The importance of speed in exercise. *Scholastic Coach*, ___, 94-99.

Coyle, E.F., Feiring, D.C., Rotkis, T.C., Cote III, R.W., Roby, F.B., Lee, W., and Wilmore, J.H. (1981). Specificity of power improvements through slow and fast isokinetic training. *Journal of Applied Physiology*, *51*(6), 1437-42.

Cybex. (1980). *Cybex II calibration procedures and record card*. New York:Cybex.

Cybex. (1983). Isolated joint testing and exercise. New York: Cybex.

Davies, A.H. (1977). Chronic effects of isokinetic and allokinetic training on muscle force, endurance, and muscular hypertrophy. Dissertaion Abstracts International, 38A, 153.

Davies, G.J. (1984). A compendium of isokinetics in clinical useage; Workshop and clinical notes. La Crosse: S&S.

De Vries, H.A. (1982). Physiology of exercise for physical education and athletics. Dubuque: Wm.C.Brown.

Edington, D.W. and Edgerton, V.R. (1976). The biology of physical activity. Boston: Houghton Mifflin.

Gondola, J.C. (1976). Three strength building programs; their effects on selected muscle groups of the knee joint after nine days of immobilization of the lower limb. Dissertation Abstracts International, 36(A), 5919.

Grimby, G., Gustafsson, E., Peterson, L., and Remstrom, P. (1980). Quadriceps function and training after knee ligament surgery. Medicine and Science in Sports, 12, 70-75.

Halbach, J.W. and Strauss, D. (1980). Comparison of electromyo stimulation to isokinetic training in increasing power of the knee extension mechanism. Journal of Orthopaedic and Sports Physical Therapy, 2(1), 20-24.

Halbach, J.W. (1983). The effects of limited range of motion exercises on full range of motion strength of the knee extensors. Unpublished master's thesis, University of Wisconsin, La Crosse.

Halling, A.H. and Dooley, J.N. (1979). The importance of isokinetic power and its specificity to athletic conditioning. Athletic Training, 14(2), 83-85.

Hislop, H.J. and Perrine, J.J. (1967). The isokinetic concept of exercise. Physical Therapy, 47(2), 114-117.

Jenkins, W.L., Thackaberry, M., and Killian, C. (1984). Speed specific isokinetic training. The Journal of Orthopaedic and Sports Physical Therapy, 6(3), 181-183.

Jensen, C.R. and Jensen, C. (1978). Update on strength training. Scholastic Coach, 48(1), 90-93.

Johnson, M.A., Polgar, J., Weightman, D. and Appleton, D. (1973). Data on the distribution of fiber types in thirty-six human muscles; An autopsy study. Journal of the Neurological Sciences, 18, 111-129.

Jurgens, W. (1978). Isokinetic strength training for rowing. The Oarsman, 6, 38-39.

Kanehisa, H. and Miyashita, M. (1983). Specificity of velocity in strength training. European Journal of Applied Physiology and Occupational Physiology, 52, 104-106.

Kearney, J.T. (1980). Resistance training: Development of muscular strength and endurance. In E.J.Burke (Ed.), Toward an understanding of human performance. New York: Mouvement.

Lamb, D.R. (1978). Physiology of exercise: Responses and adaptations. New York: MacMillan.

Lesmes, G.R., Costill, D.L., Coyle, E.F., and Fink, W.J. (1978). Muscle strength and power changes during maximal isokinetic training. Medicine and Science in Sports, 10(4), 266-269.

Magee, D. and Currier, D.P. (1984). Optimum repetitions for muscle strengthening by isokinetic exercise. Physical Therapy, 64(5), 721, (Abstract).

Mathews, D.K. and Fox, E.L. (1976). The physiological basis of physical education and athletics. Philadelphia: Saunders.

Mawdsley, R.H. and Knapin, J.J. (1982). Comparison of isokinetic measurements with test repetitions. Physical Therapy, 62(2), 169-172.

Meadors, W.J., Crews, T.R., and Adeyanju, K. (1983). A comparison of three conditioning protocols on the muscular strength and endurance of sedentary college women. Athletic Training, 18(3), 240-243.

Moffroid, M.T. and Whipple, R.H. (1970). Specificity of speed of exercise. Physical Therapy, 50, 169-172.

Moffroid, M.T., Whipple, R.H., Hofkosh, J., Lowman, E., and Thistle, H. (1969). A study of isokinetic exercise. Physical Therapy, 49(7), 735-747.

Nobbs, L.A. and Rhode, E.C. (1984). The effect of electrical stimulation and isokinetic exercise on muscular power of the quadriceps femoris. Submitted to Journal of Orthopaedic and Sports Physical Therapy.

Parker, M.G. (1981). Characteristics of skeletal muscle during rehabilitation: Quadriceps femoris. *Athletic Training*, *16*(4), 122-124.

Pipes, T.V. and Wilmore, J.H. (1975). Isokinetic v isotonic strength training in adult men. *Medicine and Science in Sports*, *7*(4), 262-274.

Pollock, M.L., Wilmore, J.H. and Fox III, S.M. (1984). *Exercise in health and disease: evaluation and prescription for prevention and rehabilitation*. Philadelphia:W.B.Saunders.

Quillen, W.S. (1981). Velocity spectrum rehabilitation with isokinetics: A protocol for clinical knee rehabilitation. *Physical Therapy*, *61*(5), 9-10.

Rozier, C.K. and Schafer, D.S. (1980). Isokinetic exercise: daily versus three times weekly. *Physical Therapy*, *60*(5), 579.

Saar, D., Ariel, G.B., Penny, M.A., and Saar, I. (1982). A strength study: Comparison between computerized exercise machine and existing modalities of weight training equipequipment. *Medicine and Science in Sports and Exercise*, *14*(2), 153. (Abstract).

Sale, D. and Mac Dougall, D. (1981) Specificity in strength training: A review for the coach and athlete. *Canadian Journal of Applied Sport Sciences*, *6*, 87-91.

Sherman, W.M., Plyley, M.J., Vogelsang, D., Costill, D.L., and Habansky, A.J. (1981). Isokinetic strength during rehabilitation following arthrotomy: Specificity of speed. *Athletic Training*, *16*(2), 138-140.

Shields, C.L., Beckwith, V.Z., and Kurland, H.L. (1985). Comparison of leg strength training equipment. *Physician and Sportsmedicine*, *13*(2), 49-56.

Smith, M.J. and Melton, P. (1981). Isokinetic v isotonic variable resistance training. *American Journal of Sports Medicine*, *9*(4), 275-279.

Van Oteghan, S.L. (1975). Two speeds of isokinetic exercise as related to vertical jump performance of women. Research Quarterly, 46(1), 78-84.

Vitti, G.J. (1984). The effects of variable training speeds on leg strength and power. Athletic Training, 19(2), 26-29.

Watkins, M.P., and Harris, B.E. (1983). Evaluation of isokinetic muscle performance. Clinics in Sports Medicine, 2(1), 37-53.

Westcott, W.L. (1984). The case for slow weight training technique. Scholastic Coach, 54(1), 42-44.

Wilmore, J.H. (1979). Letter to the editor. Medicine and Science in Sports, 11(3), iii.

Wright, K. and McNeil, A. (1979). An Orthotron knee rehabilitation program. Athletic Training, 14, 232-233.

APPENDIX A

SUBJECT INFORMATION

NAME

PHONE

AGE

SEX

****

1. Have you been involved in any weight training program using your legs, in the last 6 months? .... If yes, please give details ....

2. Have you had any knee injuries in the last 2 years?..........

   If yes, please give details ....

3. Please describe your present physical activity patterns ....

**** DO NOT COMPLETE ****

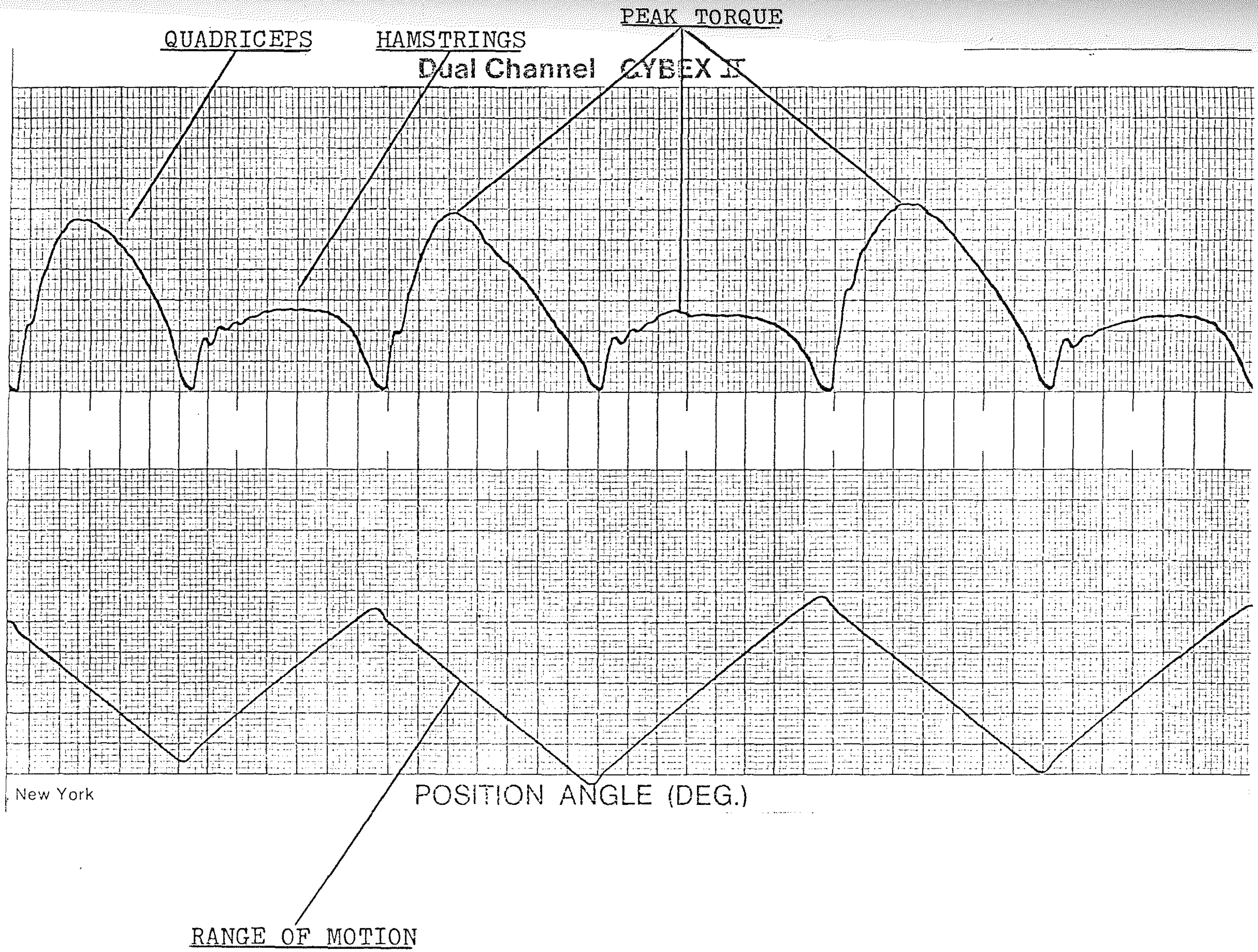
Height	Weight ....
Dominant Leg	Date (T1)
Training Group	Date (T2)

APPENDIX B

Cybex Data Reduction

Computer printout

```
30 repetition test                                      5 repetition test

LEFT SIDE DATA                                          LEFT SIDE DATA
     TEST 1                                                  TEST 1
180 DEG/SEC 30 REPS                                      60 DEG/SEC 5  REPS


     EXTENSION ──────────────── Peak torque ──────────        EXTENSION
60 FT-LBS *  43 DEG                                     113 FT-LBS *  39 DEG
44% PEAK%BW RATIO                                       84% PEAK%BW RATIO
51 FT-LBS *  30 DEG                                     95 FT-LBS *  30 DEG
55 FT-LBS ?  70 DEG                                     54 FT-LBS ?  70 DEG

     FLEXION                                                 FLEXION
43 FT-LBS *  41 DEG                                     44 FT-LBS *  43 DEG
32% PEAK%BW RATIO    ── Peak torque to  ────────────    33% PEAK%BW RATIO
34 FT-LBS *  30 DEG     body weight ratio               40 FT-LBS *  30 DEG
35 FT-LBS *  70 DEG                                     31 FT-LBS *  70 DEG
FLEXION%EXTENSION                                       FLEXION%EXTENSION
72% PEAKS                                               39% PEAKS
67%  30 DEG                                             42%  30 DEG
64%  70 DEG                                             57%  70 DEG

MAX ROM TESTED       ──Range of motion──                MAX ROM TESTED
 102 DEG    -3 DEG                                        84 DEG    -9 DEG

WORK AT 180 DEG/SEC                                     WORK AT  60 DEG/SEC

     EXTENSION                                               EXTENSION
15.39 FT-LBS PK TAE                                     3.95 FT-LBS PK TAE
1765 FT-LBS 30 REPS  ──────Total work──────             518 FT-LBS  5 REPS
 457 FT-LBS 1ST  6                                       201 FT-LBS 1ST  2
 258 FT-LBS LAST  6                                      208 FT-LBS LAST  2
57% ENDURANCE RATIO ──Endurance ratio──                 104% ENDURANCE RATIO
101 DEG AVG ROM                                          89 DEG AVG ROM
141 WATTS AVG POW    ── Average power ──                94 WATTS AVG POW

     FLEXION                                                 FLEXION
6.75 FT-LBS PK TAE                                      1.57 FT-LBS PK TAE
952 FT-LBS 30 REPS                                      176 FT-LBS  5 REPS
 249 FT-LBS 1ST  6                                       69 FT-LBS 1ST  2
 134 FT-LBS LAST  6                                      76 FT-LBS LAST  2
54% ENDURANCE RATIO                                     111% ENDURANCE RATIO
102 DEG AVG ROM                                          90 DEG AVG ROM
75 WATTS AVG POW                                        31 WATTS AVG POW

FLEXION%EXTENSION                                       FLEXION%EXTENSION
WORK RATIO = 54%                                        WORK RATIO = 34%
```



PEAK TORQUE
QUADRICEPS
HAMSTRINGS
Dual Channel CYBEX II
New York
POSITION ANGLE (DEG.)
RANGE OF MOTION

APPENDIX C

Author(s)	n	Groups	sets x repetitions	training load	times per week	comments
Adeyanju et al. (1983)	30f	1.Slow 2.Fast	3x20s 3x20s	30°/s 180°/s	3 / 7w	Both groups improved significantly. Fast group improved most.
Blattner & Noble (1979)	48m	1.Isokinetic 2.Plyometric	3x10 3x10 depth jumps	n/a	3 / 8w	No significant differences.
Caizzio et al. (1980)	17	1.Slow 2.Fast	8s 8s	96°/s 240°/s	3 / 4w	Significant increases at specific speeds.
Carr et al. (1981)	10	1.Slow 2.Fast	n/a n/a	42°/s 192°/s	3 / 9w	Both improved significantly.No reported differences between groups.
Coyle et al. (1981)	22m	1.Slow 2.Fast 3.Mixed	5x6 5x12 2-3 sets of the above	60°/s 300°/s	3 / 6w	Fast group improved most.
Davies (1977)	176m	9 groups training with combinations of 5,10,15 reps. at 1,2.5,4 sec/rep.			3 / 9w	4sec/rep. group significantly better at 7.5s/rep.
Gondola (1976)	15f	1.Isokinetic 2.Isotonic 3.Isometric	3x6 10x10 6x5sec	n/a increasing load 90,120,180°	5 / 2w	No significant differences
Grimby et al. (1980)		1.Isokinetic 2.Isotonic	3x10 3x10	42°/s 10RM	3 / 6w	No significant changes.
Halbach &Strauss (1980)		1.Isokinetic 2.E.M.S	2x10	150,210,270°/s	n/a 3w	Isokinetic group significantly better.
Jenkins et al. (1984)	24	1.Slow 2.Fast	1x15 1x15	60°/s 240°/s	3 / 6w	Speed specific improvements.
Kanehisa & Miyashita (1983)	21	1.Slow 2.Intermediate 3.Fast	10 30 50	60°/s 180°/s 300°/s	6 / 8w	Slow and intermediate groups improved at all speeds. Fast group improved only at fast speeds.
Lesmes et al. (1978)	5m	1.Isokinetic 2.Isokinetic	10x6sec 2x30sec	180°/s 180°/s	4 / 7w	No significant differences between groups.
Magee & Currier (1984)	55f	6 groups trained with 1 set of 6,8,10, 12,14 or 16 repetitions @ 30°/s.			2w	No significant differences between groups.
Meadors et al. (1983)	27	1.Isokinetic 2.Isotonic 3.Isotonic	3x5 3x10 1x1	180°/s for 20s. 10RM %of1RM	3 / 8w	No significant differences between groups.
Moffroid et al. (1969)	60	1.Isokinetic 2.Isotonic 3.Isometric	30 3x10 10	n/a n/a 90°&45°	7 / 4w	Isokinetic group improved significantly more than the others.
Moffroid & Whipple (1970)	30	1.Slow 2.Fast	20 60	36°/s 108°/s	3 / 6w	Slow group improved specifically. Fast group improved at all speeds.
Nobbs & Rhode (1984)	27f	1.Isokinetic 2.E.M.S 3.EMS/Isok.	n/a n/a n/a	30°/s - -/30°/s	3 / 6w	No significant differences between groups.
Pipes & Wilmore (1975).	36m	1.Isotonic 2.Slow 3.Fast	3x8 3x8 3x15	75%of 1RM 24°/s 130°/s	3 / 8w	Isokinetic fast group improved most.
Rozier & Schafer (1980)	23f	1.Isokinetic 2.Isokinetic	3x8 3x8	300°/s 300°/s	5 / 6w 3 / 6w	No significant differences between groups.
Saar et al. (1982)	48	1.Isokinetic 2.Isotonic (Universal) 3.Free weights	n/a 3x10 3x10	n/a n/a n/a	3 /12w	Isokinetic group improved significantly more than the other groups.
Shields et al. (1985)	53	1.Isokinetic 2.Isotonic	n/a 2x10	30-121°/s n/a	3 / 8w	Neither group had a significant advantage.
Smith & Melton (1981)	12m	1.Slow 2.Fast 3.Isotonic	30,60,90°/s until 50% fatigue 180.240,300°/s " " " 3x10		3/ 6w	Isokinetic groups improved at all speeds.
Van Oteghan (1975)	48f	1.Fast 2.Slow	3x10 3x10	2sec. 4sec	3 / 8w	Only slow group improved in strength.
Vitti (1984)	30m	1.Slow 2.Fast 3.Mixed	1x30sec 1x30sec 1x30sec	60-150°/s 210-300°/s 60-300°/s	3 / 6w	No significant differences between groups.

APPENDIX D

Informed Consent Form

Project Title: The optimal number of repetitions to be used in isokinetic strength, power, and endurance training.

Principal Investigator: Stephen Bendle

Procedure: All subjects will perform 5 maximal isokinetic contractions of the knee flexors and extensors at 60, 120,180,240,and 300 degrees/second on the Cybex II dynamometer. There will be two testing sessions which will be 6 weeks apart. Prior to each testing the subject will perform 5 submaximal and one maximal isokinetic contraction. The test will be performed bi-laterally.

After the initial testing the subjects will be randomly assigned to training groups. They will be A) Control - no repetitions, B) 5 repetitions, C) 10 repetitions, D) 15 repetitions, E) 20 repetitions.

Training will cosist of 3 sets of the assigned repetitions, 3 days per week for 6 weeks on the non-dominant leg only. Following the 6 week training period, the testing will be repeated.

Potential discomfort or risk: Each subject may feel muscle soreness for a short time after testing. Each subject also has a risk of straining or spraining the knee joint during testing.

Potential benefits: The determination of the optimal number of repetitions to be used with isokinetic training would play an important role in establishing optimal isokinetic training protocols. These could then be used in rehabilitation of injuries or the development of strength, power and endurance.

The principal investigator will answer any and all inquiries concerning procedures, risks or benefits.

1. I, ______________________________ being of sound
(Name of Subject)
mind and____________ years of age, do hereby consent to authorize and request the person named above (and his co-workers, agents and employees) to undertake and perform on me the proposed procedure, treatment, research or investigation (herein called 'procedure`).

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

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

4. I understand that I may withdraw from the program at any time. Signed at _____________________________ this _______________ day of _______________ 19_____, in the presence of the witnesses whose signatures appear opposite my signature.

__________________________ __________________________
(Subject) (Witness)

APPENDIX E

CYBEX II CALIBRATION PROCEDURES AND RECORD CARD

Torque Channel Calibration for Single and Dual-Channel Chart Recorders

It is recommended that the torque channel of CYBEX II Single and Dual-Channel Chart Recorders be calibrated each month to insure the accuracy of the force output measurement on the chart recording. The torque channel has three torque range scales, each of which must be calibrated separately. The calibration T-bar provided with each CYBEX II System makes this a simple procedure.

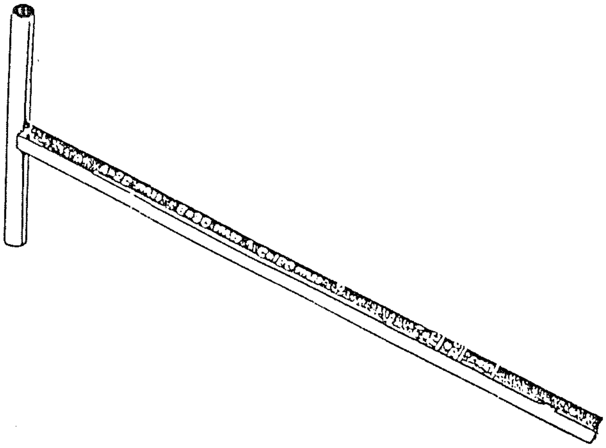


Fig. 1

There are two types of calibration T-bars. The newer design (standard on units shipped after September 1, 1980) has permanently engraved markings designated as A, B and C (see Fig. 1). These indicate the proper *effective input arm length* setting for each part of the calibration procedure. Also shown is the correct amount of weight to apply to the T-bar at each setting. The old design T-bar requires measuring the *effective input arm length* with a tape measure. How both of the calibration T-bars are used is further explained in the instructions below.

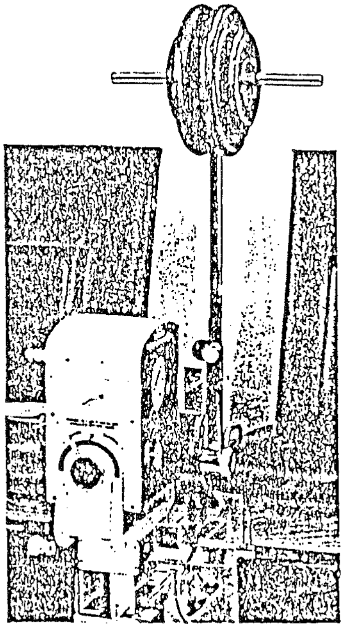


Fig. 2

How to Use the Calibration T-Bar:

The calibration T-bar is inserted into the long input adapter (see Fig. 2) so that the holes on the side of the T-bar engage with the pull-button of the input adapter at a predetermined length called the *effective input arm length.* The effective input arm length setting for each of the foot-pound scales is shown in the Torque Channel Specifications Chart on page 3.

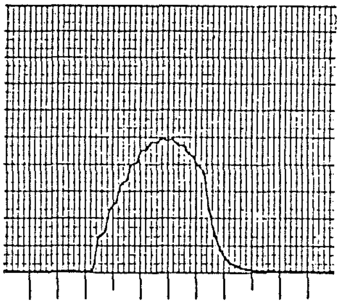
Once the effective input arm length is established, an amount of disk weights (see Specifications Chart) must be added to the T-bar. The weights, combined with the torque value of the T-bar, will produce the appropriate force input for calibration. MAKE SURE THE WEIGHTS YOU USE FOR CALIBRATION ARE ACCURATE. STANDARD DISK WEIGHTS ARE FREQUENTLY OFF ±5-10% OF STATED WEIGHT.

To calibrate CYBEX II torque channel, follow steps 1-9 for each of the foot-pound scales:

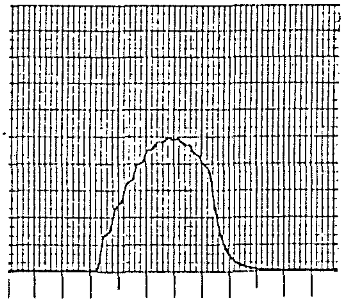
First, "zero" or "null out" the baseline using the following procedure—

A. Set damping control at zero, chart paper at 5 mm/sec and speed selector at 30°/sec (5 RPM). Make sure there is no load on dynamometer.
B. Set foot-pound scale on 180 and zero recorder stylus on baseline using zero adjust knob on recorder.
C. Switch foot-pound scale to 30.
D. If stylus deflects from baseline, adjust "zero null" potentiometer (see Figs. 3 & 4) on recorder with screwdriver to zero stylus on chart baseline.
E. Repeat steps B thru D until stylus deflects no more than ½ minor division when switching back and forth between 180 and 30 ft. lb. scales.
F. Set chart speed at "Standby."

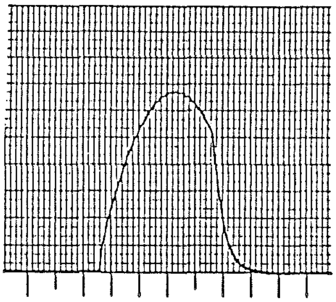
1. Set torque channel to foot-pound scale to be calibrated. (Begin with the 360 ft. lb. scale, then 180 ft. lb. scale, and lastly the 30 ft. lb. scale.) Set damping control at 3. 4
2. Set speed selector at 30°/sec. (5 RPM) and make sure there is no load on the dynamometer. Zero baseline using zero adjust knob on recorder.
3. Insert T-bar into long input adapter and set effective input arm length for foot-pound scale being calibrated (see Specifications Chart).
4. Add appropriate amount of disk weights for foot-pound scale being calibrated (see Specifications Chart).
5. Set chart paper speed at 5mm/sec.
6. Lift weighted T-bar to vertical position above dynamometer as shown in Fig. 2. Pull weighted arm forward gently to engage isokinetic resistance, so that arm falls smoothly until it contacts the floor.
7. Check the torque reading on the chart recording. The peak value for each of the foot-pound scale settings should be as follows:



360 ft. lb. scale—5 major divisions above baseline
(180 ft. lbs.)



180 ft. lb. scale—5 major divisions above baseline
(90 ft. lbs.)



30 ft. lb. scale—20 minor divisions above baseline
(20 ft. lbs.)

The above values are derived from the following formula:

(distance in feet × disk weights in pounds) + torque value of T-bar = total torque in ft. lbs.

Using the 180 ft.lb. scale as an example:
(2.58 ft. × 32.5 lbs.) + 6.2 ft. lbs. = 90 ft. lbs.

8. If the chart recording does not agree with the above value, adjust the potentiometer for that particular foot-pound scale (see Figs. 3 & 4) with the special yellow calibration screwdriver or any small screwdriver. Turning the potentiometer clockwise increases the torque reading, counter-clockwise decreases it.
9. Once the torque value is correct, re-check twice to make sure reading is consistent.

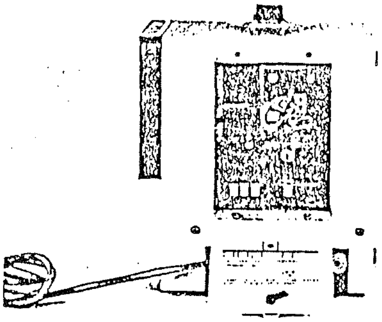


Fig. 3

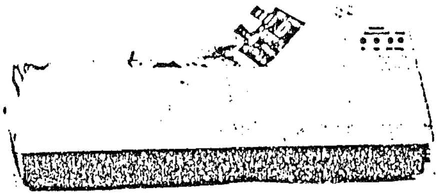


Fig. 4

CYBEX II TORQUE CHANNEL CALIBRATION SPECIFICATIONS CHART

		Torque Channel Foot-Pound Scales		
		360 ft. lb.	180 ft. lb.	30 ft. lb.
Effective Input Arm Length	Old T-Bar*	30″	31″	33″
	New T-Bar	C	B	A
Disk-Weights (in pounds)		70	32.5	5

*Measure distance from center of dynamometer input shaft to center of calibration T-bar cross-tube.

Position Angle Channel Calibration for Dual-Channel Recorders

Like the torque channel on Single and Dual-Channel Recorders, the position angle channel is calibrated at the factory, but may require occasional checking or recalibration. There are two degree scale settings (150° and 300°). Calibrating either one calibrates the other as well. Since most joint patterns have less than 150 degrees range of motion, the 150° scale is the one most often calibrated. This brings the accuracy of the 150° scale to ± 1.5° (± 1%) while the 300° scale accuracy is ± 6° (± 2%).

If greater accuracy for movement patterns larger than 150° is desired, calibrate the 300° scale directly. This achieves ± 3° (± 1%) accuracy for the 300° scale; accuracy of the 150° scale decreases to ± 3° (± 2%).

To calibrate CYBEX II position angle channel, use the following procedure:

1. Set chart paper speed at 5 mm/sec.
2. Set Input Direction switch to clockwise (CW).
3. Turn goniometer dial (see Fig. 5) clockwise until stylus moves to chart baseline, and note degree reading on goniometer dial indicated by thin white "marker" line etched in the mounting plate between the goniometer dial and bottom gear.
4. Choose either 150° or 300° scale.
5. Turn goniometer dial clockwise through either 150 or 300 degrees, depending on scale chosen in step 4.
6. Recorder stylus should lie at top line of position angle channel chart. If not, adjust the "Deg.Cal." screw on the recorder by loosening the locking nut and turning the adjusting screw until the stylus is at the top of the chart. Retighten locking nut while holding screw in proper calibration position with screwdriver.
7. Repeat procedure to recheck setting.
8. Set Input Direction switch to counterclockwise (CCW) and repeat steps 3 through 7, turning the goniometer dial counterclockwise instead of clockwise in steps 5 and 6.

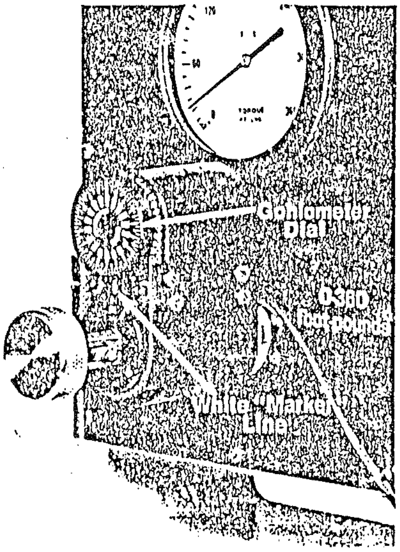


Fig. 5

Speed Selector Calibration for Single and Dual-Channel CYBEX II Systems

Though seldom required, calibration instructions for the Speed Selector are included in this brochure so that you may be completely assured of the accuracy of the CYBEX II system. Calibration of the Speed Selector requires a stopwatch and a few standard CYBEX II input accessories.

continued on page 4

To check, and if necessary calibrate, the Speed Selector, use the following procedure:

1. Turn dynamometer so that it faces 180° away from S-H-D Tables.
2. Attach long input adapter, adjusting arm, handgrip and locking collar w/wing screw to dynamometer input shaft as shown in Fig. 6.
3. Turn Speed Selector ON and set speed at 30 RPM* (180°/sec.).
4. Beginning with the input arm at either the twelve or six o'clock position relative to the dynamometer face, manually turn the input arm (either direction), counting the number of revolutions in 30 seconds. Use a stopwatch as a timer. *You need put only enough force into the unit that the torque gauge reads 20 ft. lbs. while turning the input arm.* You may wish to verify that applying more force does not change the speed.
5. If properly calibrated, you should complete 15 revolutions in 30 seconds. If not, a potentiometer inside the speed selector must be adjusted. To do this, remove the sheet metal covering from the top of the speed selector. Adjust the potentiometer (R77) at the bottom of the first printed circuit board as shown in Fig. 7. Use a plastic screwdriver and make *very slight* adjustments. CAUTION: THIS IS A SIMPLE ADJUSTMENT. HOWEVER, IT IS POSSIBLE TO SHORT CIRCUIT THE SPEED SELECTOR OR CREATE A SHOCK HAZARD BY TOUCHING OTHER ELECTRICAL COMPONENTS. USE A PLASTIC HANDLED OR SPECIAL CALIBRATION SCREWDRIVER AND AVOID TOUCHING COMPONENTS OTHER THAN R77 POT. If speed is too fast (more than 15 revolutions in 30 seconds), adjust potentiometer counter-clockwise. If speed is too slow (less than 15 revolutions in 30 seconds), turn potentiometer clockwise.

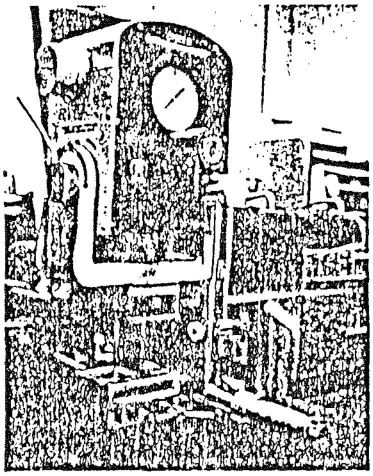


Fig. 6

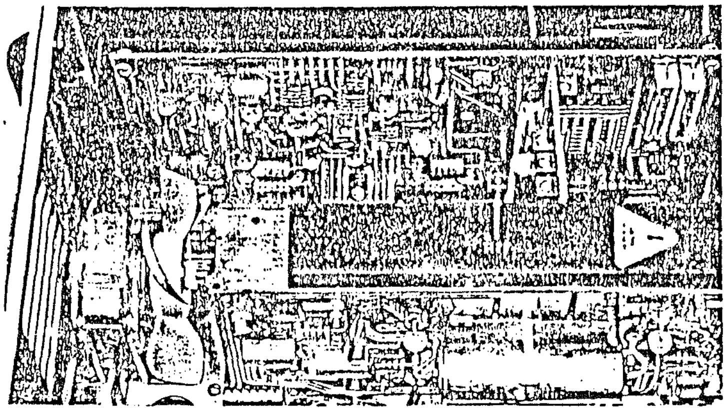


Fig. 7

*Other RPM settings can be used. In which case, 1/2 of that RPM value is the number of revolutions you should get in step 5.

See "Isolated-Joint Testing and Exercise. . . A Handbook for Using the CYBEX II" for complete system accuracy and performance standards.

CYBEX II Calibration Record

DATE	Torque Channel				CYBEX II Dual Channel Only	Speed Selector	Comments*	Name or Initial
	"Zero Null"	30 ft-lbs	180 ft-lbs	360 ft-lbs	Position Angle Channel (Indicate scale calibrated)			

*Indicate in comments section what, if any, calibration adjustments were needed. If not indicate "all calibration OK."

APPENDIX F

TESTING AND EXERCISE OF THE KNEE

Anatomical Considerations

Although the largest and most complex joint in the human body, the knee is the easiest joint to test and exercise on CYBEX II. Also, far more clinical data is available on the knee than on other joints.

All of the major knee flexors, as compared to only one of the major knee extensors, are two-joint muscles with origins above the hip joint. This fact dictates the optimal testing and exercise position for knee extension/flexion which is established by the CYBEX knee testing tables. This positioning allows the flexors to be worked at an advantageous and reproducible length/tension relationship without restricting extensor range of motion. A number of studies have verified that this positioning produces maximum flexor and extensor forces with excellent reproducibility. Fortunately, it is also convenient and comfortable for most patients.

If this positioning is not practical or appropriate for certain patients (e.g., extensors require gravity assist, hip flexion limited to less than 90°), positioning the patient prone on the U.B.X.T. is a recommended alternative. See pages for "ankle plantar/dorsiflexion straight-legged" as example.

Although conditioning the extensors and flexors must be a primary goal in knee rehabilitation, the importance of testing and exercising internal/external rotation in many cases cannot be over-emphasized. The popliteus and medial hamstrings (as internal rotators) and the biceps femoris and tensor fasciae latae (as external rotators) can play a significant role in supporting the knee with rotatory and/or anterior or posterior instability. Pes anserinus transfer may further enhance this action. Clinical study has demonstrated that specific rehabilitation in this pattern is essential for maximum functional return in many cases. Furthermore, testing this movement pattern provides excellent data on the specific functional capability of these muscles. Also to be considered in anterior instabilities is the importance of the gastrocnemius.

Limiting range of motion is rarely necessary in knee movement patterns. If indicated for certain types of pathology, or in the early stages of rehabilitation after certain surgical procedures or trauma, flexion may be limited with an adjustable stool or chair placed under the foot. Extension and internal or external rotation can be blocked only manually.

Anatomical landmarks of the knee are easily palpated so that the axes of rotation for testing are readily located. The mixed gliding and rocking action of the knee joint in extension/flexion does cause this axis to shift slightly as the femoral condyles slide anteriorly during flexion and back posteriorly during extension. However, this small shift has no significant effect on the chart recording. As explained in the next section, aligning axes of rotation for knee testing is rarely a problem.

About the only anatomical problems presented in knee testing have to do with patient comfort and with the normal hyperextension of the joint. It is desirable to maximally stabilize the thigh in extension/flexion. But, if there is insufficient padding underneath the thigh, or the strap over the thigh is too tight, force output will likely by inhibited by discomfort in the working muscles.

Compounding this problem is the normal range of hyperextension. The degree of hyperextension seen in a knee test is affected by the test speed. At slow test speeds, no hyperextension may be noticeable. But, at higher test speeds, the inertia of the limb tends to help the contracting muscles overcome the passive resistance of skin, fascia and articular structures so that significant hyperextension occurs. Also, it is possible for the thigh to lift off the table slightly. The position angle stylus shows this extra movement by traveling below the 0° baseline.

These factors have no significant effect on torque measurement except possibly during the first one-tenth second of a high-torque contraction during which the limb "takes up slack" in the straps and/or compresses the foam padding of the table and shin pad. At lower force levels such as those common in high-speed testing, this factor is even less significant on the torque graph.

These factors can, however, combine to produce errors of ±5° on the position angle graph depending on force and direction of movement. This amount of error can occur only in knee extension/flexion testing. It is considered acceptable in clinical applications because the overall range of motion measurement is quite accurate and the position of any specific torque measurement can still be rather closely identified. In fact, a number of studies have shown that manual goniometric measurements are rarely more accurate than ±5°.

General Positioning and Stabilization Guidelines

First of all, to minimize possible error in extension/flexion testing from the factors just discussed, always make thigh and shin pad straps as tight as comfortably tolerable. Placing the shin pad just proximal to the malleoli below the bulk of calf musculature is also recommended.

It has been noted that the axis for extension/flexion testing is easily located. You will find that the vertical location of this axis when seated on the knee testing tables varies negligibly from patient to patient. It is rarely necessary to raise or lower the dynamometer from a standard position 3/4" higher than top of of table upholstery (measured from center of input shaft). The exceptions are children or slender females (lower dynamometer slightly) and very large, obese, or heavily muscled individuals (raise dynamometer slightly).

Similarly, it is rarely necessary to move the dynamometer in or out relative to the knee testing tables. A position 1 3/4" out from front edge of table upholstery will allow horizontal axis alignment for all but very small or very large individuals. Move patient back on seat as far as possible with knees flexed to at least 90°. Make sure to use supplied "spacer" pads if necessary to give patient solid back support.

Upper-body stabilization is usually accomplished voluntarily by the patient. It is possible to use the U.B.X.T. torso stabilization strap around the upper thigh and pelvis by looping it through the side handgrips. Some users have patients fold their arms across their chest. Others have patients grasp the side handgrips. Consistent positioning is recommended, but, as long as patients keep their back firmly against the backrest (no rocking), little difference is likely in test results.

Positioning for tibial internal/external rotation is quite straight-forward and requires no further explanation than given on the positioning instruction pages. It should be noted, however, that testing and exercise can be done at different knee and hip angles than those suggested. Simply make sure to note and reproduce the same angles each time testing is performed.

KNEE *Extension/Flexion*

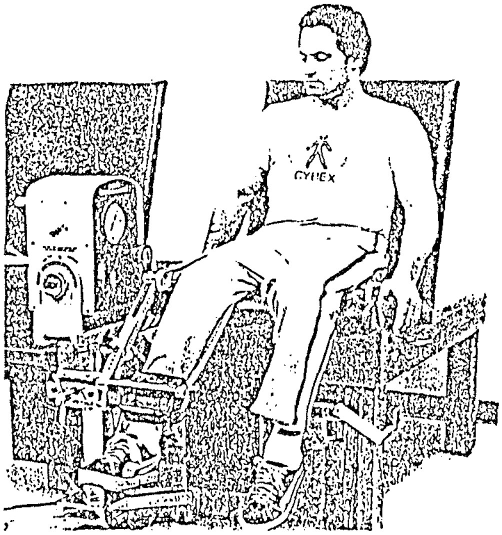


Fig. 1

- Use back "spacer" pads as necessary to move patient forward or backward to align axis of rotation and provide solid, comfortable backrest.
- Thigh stabilization strap
- Torso stabilization strap (D) from U.B.X.T. may be used to stabilize pelvis by attaching to side handgrips of S-H-D table if desired.

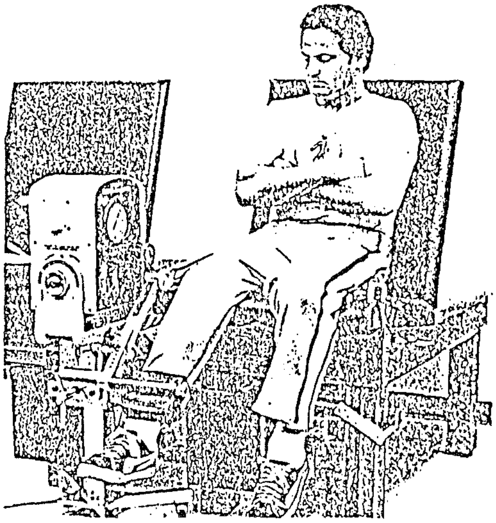


Fig. 2

- Special brackets and straps for pelvic and torso stabilization will be available approximately Nov. 1, 1981. These may be ordered from Cybex Customer Service.
- Some users have patients hold on to sides of table, others prefer not to allow patients to hold on to anything. No published information is currently available regarding which is better as long as the same positioning is always used. When the pelvic and torso stabilization straps are available Cybex will recommend the crossed-arm position shown in Fig. 2.

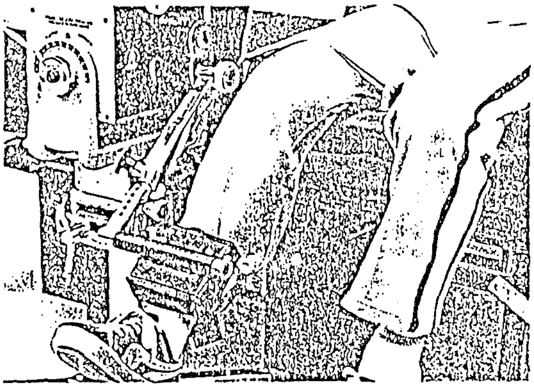
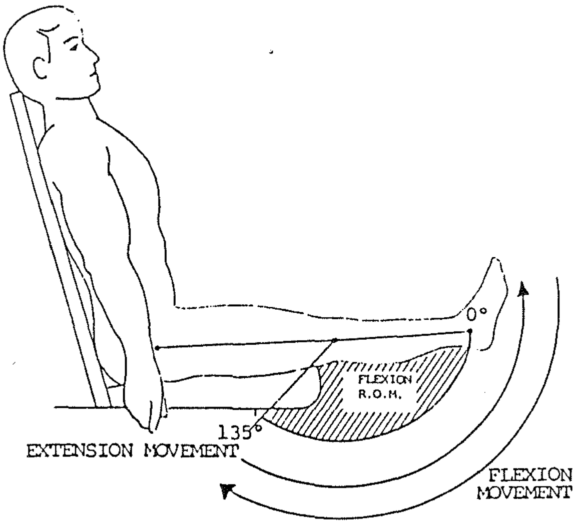


Fig. 3

- Long input adapter (T) with adjusting arm (X)
- Shin pad with padded Velcro strap (V)
- Shin pad adjustment length does not affect torque measurement (see explanation pg. 10, par. 4-6). Therefore, shin pad may be placed where most comfortable for patient. For testing consistency, however, it is recommended that the shin pad be placed so that its bottom edge is level with the superior border of the medial malleolus.

KNEE *Extension/Flexion*



- Limb movement occurs in sagittal plane
- Instantaneous axis of rotation changes slightly throughout movement and from extension to flexion because of mixed gliding and rocking motions of articular surfaces. These small changes do not affect test accuracy.
- Because the axis of rotation of the knee changes slightly from flexion to extension, the most accurate fixed axis for exercise or testing purposes is a line passing transversely through the famoral condyles. It is rarely necessary to adjust dynamometer height or distance from table for small differences between most patients.
- As much as 10° of hyperextension is considered normal. Clinically, the fully extended and locked knee is commonly used as "zero" when setting position angle stylus. At fast test speeds, limb inertia will overcome resistance of skin, fascia and articular structures to hyperextension causing position angle stylus to measure a few degrees below 0° baseline. See introduction for further explanation.
- Contact of heel with padded table leg clamp will limit flexion to approximately 105°.

KNEE EXTENSION/FLEXION
Rotate dynamometer to face right or left depending on side to be tested and attach accessories as indicated in Fig's. 1 & 2.
Position and stabilize patient on appropriate S-H-D table. Move patient back on seat as far as possible with knees flexed to at least 90°. Use back pads supplied with knee testing tables if necessary to give solid back support. Shin pad should be placed just proximal to Malleoli. Shin pad strap and thigh strap must be as tight as comfortably tolerable. See introduction to knee testing section for comments on upper-body stabilization.
Select *30, 180,* or *360* ft. lbs. scale and check zero torque baseline on *TORQUE CHANNEL*. Select *DAMPING 2*.
Select *150°* scale and check *ZERO TEST* on *POSITION ANGLE CHANNEL*.
Position and lock patient at anatomical zero (Fig. 3) by turning speed selector to 0°/sec. (not *OFF*).
Set *INPUT DIRECTION CW* for left limb - *CCW* for right limb.
Set 0° baseline at bottom of *POSITION ANGLE CHANNEL* by turning goniometer gear dial.
Standardize instructions to patient. Allow 5-10 warm-up/familiarization repetitions at each test speed. Check tightness of locking knobs.
Start test in full flexion. Set *CHART SPEED* as required for test protocol.

Letters after listed accessories refer to "Illustrated Parts List" on pg. 3.

APPENDIX G

"Quick Reference" Procedure Checklist

1. Recorder power *ON*. *CHART SPEED* set to *STANDBY*.
2. Speed selector *ON*. *SPEED* set to at least *60°/sec*.
3. Position dynamometer and attach appropriate input accessories.
4. Adjust U.B.X.T. seat and back, and attach appropriate stabilization accessories.
5. Position patient on U.B.X.T. Adjust stabilization accessories and secure pelvic and torso stabilization straps.
6. Align joint axis with dynamometer input shaft. Set input accessory arm length to match limb segment length.
7. Check axes alignment and input accessory length by having patient move back and forth through complete active R.O.M. Correct as necessary.
8. Select *30, 180* or *360* ft. lbs. torque range scale.
9. Check zero torque baseline by momentarily switching to *25mm/sec. CHART SPEED*. Adjust as necessary.
10. Select *150* or *300* position angle degree scale.
11. Check *Position Angle Channel* calibration setting by briefly depressing *ZERO TEST* button.
12. Position patient at *anatomical zero* and lock by setting speed selector to "0." (not *OFF*).
13. Set *CW* or *CCW INPUT DIRECTION*.
14. Set appropriate zero degree baseline by turning goniometer gear dial to adjust position angle stylus.
15. Begin standardized instructions and explanation to patient. Allow 5-10 warm-up/familiarization repetitions at each test speed to be used. Set *SPEED* to first test speed of protocol and have patient assume indicated starting position.
16. Set recorder *CHART SPEED* as required according to test protocol and begin test sequence.

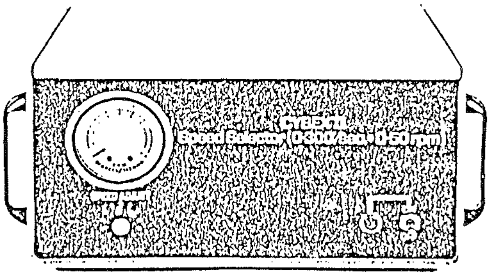
APPENDIX H

EXERCISE/TESTING PROCEDURE

1. If testing, push recorder *POWER* button switch to *ON*. Set *CHART SPEED* switch to *STANDBY*.

2. Set speed selector switch to *ON*. Set *SPEED* control knob to any speed above 60 degrees per second so that input shaft moves freely allowing you to work more easily with input accessories and patient positioning.

3. Position dynamometer and attach appropriate input accessories according to instructions and photographs for movement pattern to be tested.



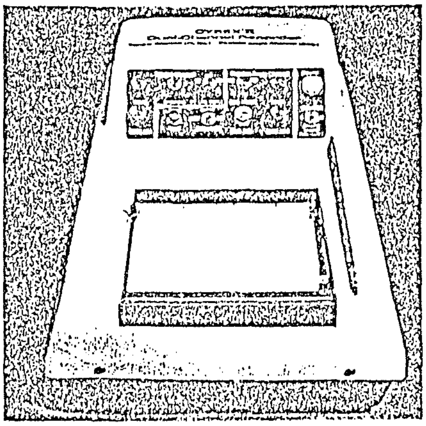
4. Adjust U.B.X.T. seat and back angles and attach appropriate stabilization accessories (footrest, universal adapters, handles, pads, etc.) as shown. These will be individually adjusted to establish and stabilize patient in a standard, reproducible body position according to instructions for each test pattern.

5. Position patient on U.B.X.T. and adjust stabilization accessories. Secure pelvic and torso stabilization straps as tight as comfortable for patient. Torso stabilization strap location may have to be re-adjusted for certain shoulder movement patterns and for female patients.

6. According to appropriate positioning photos and illustrations, align axis of rotation of joint movement pattern as close as possible "by eye" with dynamometer input shaft. Set input accessory arm length to match limb segment length of patient. Note that for ankle and wrist patterns, this length adjustment primarily controls alignment of rotational axes.

7. As applicable, secure all straps and/or have patient grasp accessory handgrip. Have patient move through complete active range of motion to check that alignment of rotational axes and accessory arm length are correct. *IMPORTANT - read thoroughly sections on "Responsibility for Safe Testing and Exercise Procedures" and "Proper Placement of the U.B.X.T. in Relation to the Dynamometer and Correct Length Adjustment of Input Accessories."*

(Recorder adjustment and setting - if not testing, skip #8-14 on following pages)



Dual-Channel Recorder

8. Select torque range scale of *30, 180,* or *360* ft. lbs. full scale depending on joint being tested and strength of patient. Most testing is done on the *180* ft. lbs. scale, but it may be necessary to change scale after observing patient's force output during warm-up repetitions.

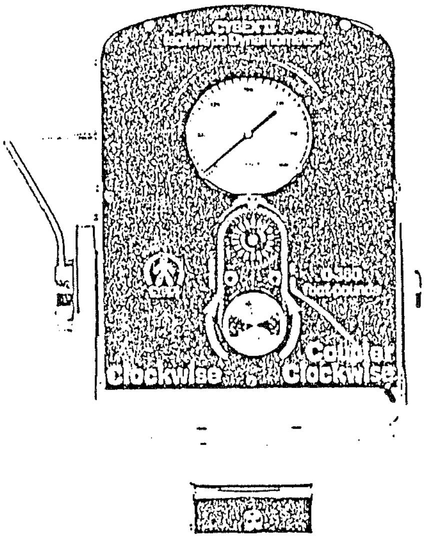
9. Momentarily switch *CHART SPEED* to *25mm/sec.* to ensure that torque stylus tracks right on bottom baseline of torque channel chart at test speed. (See section on selecting chart paper baselines.) If necessary, adjust with *Torque Channel ZERO ADJ.* knob. *Make sure speed selector is set to test speed of at least 30 degrees/second and that there is no torque input or load on dynamometer when setting zero torque baseline.*

10. Select appropriate position angle degree scale of *150°* or *300°* full scale. This is determined simply by the total degrees of movement that is considered normal for the joint pattern being tested. The "normal" ranges of motion shown in the line drawings for each pattern in this handbook are those determined by the American Academy of Orthopaedic Surgeons Committee on Joint Motion. There is some disagreement on these norms among all sources checked. Alternatively, the range of motion of the uninjured/uninvolved limb might be considered as "normal" for evaluation purposes.

11. To check *Position Angle Channel* calibration, briefly depress and hold *ZERO TEST* button. Whenever this button is held depressed, position angle stylus should track right on bottom baseline of chart paper. (See section on selecting chart paper baselines.) If it does not, adjust with *ZERO ADJ.* knob *while keeping ZERO TEST button depressed.* Remember that this is a calibration function and has nothing to do with the specific movement pattern being tested. Do not touch or adjust this knob for any other purpose.

12. Have the patient move to the *anatomical zero* position as shown in the appropriate line drawing. This should be checked with a goniometer when highest possible accuracy is required. (See appendix section on "Standards of Accuracy..." for comments on goniometry and specific problems involved in precise range of motion and angular position measurement.) At this point, turn the speed selector to "0" speed (*NOT OFF*) to hold the patient at anatomical zero while making final adjustments that follow. If patient has limited R.O.M. and cannot reach anatomical zero, this position will have to be calculated and set from goniometric measurements.

13. Set *INPUT DIRECTION* to *CW* (clockwise) or *CCW* (counter-clockwise) as indicated. This is determined by looking at the face of the dynamometer as if it were a clock. In which direction will the *major* range of motion *away from anatomical zero* occur? This switch must be set accordingly before setting the zero degree baseline with the electro-goniometer (next).



14. Set the position angle stylus to the indicated zero degree baseline on the chart paper by turning the goniometer gear dial on the dynamometer. This gear has a clutch mechanism that allows it to be turned independently of the input shaft without loosening the input adapter or locking collet. Note that if an input adapter is loose on the input shaft, the goniometer gear will not turn with the input shaft during testing or will only engage sporadically. Consequently, the Position Angle Channel on the recorder will not function properly. So, make sure input adapter is all the way on shaft and that locking collet is tightened. *IMPORTANT - read thoroughly section on "Selecting Appropriate Zero Baselines on Chart Paper."*

(If any of the adjustments explained in items 11-14 are made incorrectly, the position angle stylus may jump off scale at one point in the range of motion. Go through these steps again in order if this occurs.)

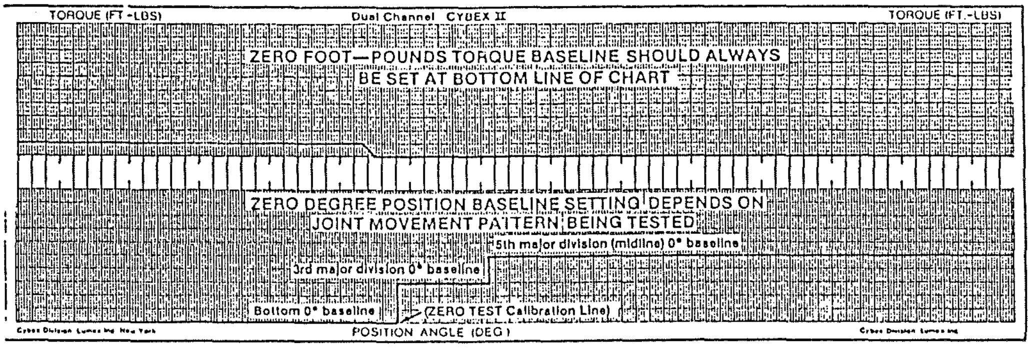
15. Set the speed selector to the desired speed for each test to be performed or for the specific exercise or rehabilitation protocol being used. When testing it may sometimes be necessary to slightly reset the torque channel stylus to baseline when changing from a slow to fast test speed. This may be particularly noticeable on the very sensitive 30 ft. lbs. scale. In any case, this in no way affects accuracy. Wherever the torque stylus rests (assuming there is no load on the dynamometer) is the actual zero line. Also when testing, make sure to allow the patient 5-10 warm-up/familiarization repetitions at each speed setting before starting test.

16. If testing, set recorder *CHART SPEED* switch to *5mm/sec.* (1 or 2mm/sec. on older recorders) for tests which require only peak torque measurement (e.g., "strength," power-endurance). Set this switch to *25mm/sec.* (50mm/sec. on some older recorders) for tests requiring an expanded torque curve or specific time measurement (e.g., torque through full R.O.M., time-rate of tension development, neuromuscular control and inhibition tests).

> NOTE: Adjustments other than explained above are rarely required. Checking calibration and re-calibrating if necessary are explained in the CYBEX II Calibration Procedures and Record Card.

Although these 16 steps may seem complex and time consuming on reading, they require no more than a few minutes for even the most difficult of the testing patterns. A synopsis of these steps for quick reference appears on page #19.

SELECTING APPROPRIATE ZERO BASELINES ON CHART PAPER



Dual-Channel recorder chart paper shown above approximately half actual size.

The torque stylus of the recorder should always be set at the bottom baseline of the *Torque Channel* chart as illustrated above. To properly set the zero torque baseline, it is important to make sure there is no input force or load on the dynamometer. Speed selector must be *ON* and set to at least 30 degrees per second. Set torque stylus with *Torque Channel ZERO ADJ.* knob.

When testing it may sometimes be necessary to slightly reset the torque stylus to baseline when changing from a slow to fast test speed. (See #15 under "EXERCISE/TESTING PROCEDURE...Step by Step Explanation.")

Selecting the correct zero degree baseline on the *Position Angle Channel* requires an understanding of how the measurement system works and of the joint movement pattern being tested. First of all, remember that *the zero degree baseline is not set with the ZERO ADJ. knob.* This knob is for calibration purposes. (See #11 under "EXERCISE/TESTING PROCEDURE...Step by Step Explanation".) The degree scale printed on the goniometer gear dial face is also for calibration and should be generally disregarded.

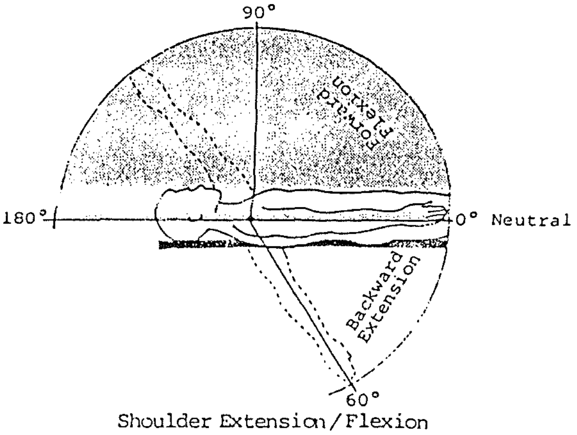
Before adjusting the position angle stylus, the appropriate recorder settings for position angle degree scale (*150* or *300*) and INPUT DIRECTION (*CW* or *CCW*) must be selected. Also, the patient must be properly positioned, stabilized and locked at the anatomical zero position. (See #10, 12 and 13 under "EXERCISE/TESTING PROCEDURE...Step by Step Explanation.")

The position angle stylus is precisely controlled by an electro-goniometer that is directly coupled to the input shaft of the dynamometer. Depending on the recorder settings mentioned above, every goniometer position has an exactly corresponding stylus position. To accommodate the many different joint patterns and ranges of motion, the electro-goniometer has a positive clutch mechanism that allows it to be turned independently of the input shaft. By manually turning the goniometer gear dial, you are simply matching a particular electro-goniometer position to the input shaft position where the patient is at anatomical zero and simultaneously "telling" the recorder where on the chart paper you want this zero point displayed. (See #14 under "EXERCISE/TESTING PROCEDURE...Step by Step Explanation.")

The position angle stylus should always be set to one of the three zero degree baselines shown in the chart paper illustration at the beginning of this section. This setting is determined by the joint movement pattern being tested. The zero degree baseline cannot always be at the bottom of the chart because many patterns have range of motion on both sides of the anatomical zero position. Varying the zero baseline allows the full range of motion to be charted and measured without going off the chart paper.

For example, shoulder flexion/extension range of motion can exceed 180° on one side of anatomical zero and 60° on the other. To ensure getting all of this on the chart paper, using the 300 degree scale setting of course, the third major division must be used as the zero degree baseline. This setting allows 210° of measured range above the baseline (flexion) and 90° of range below (extension).

For quick reference without figuring, all appropriate *Position Angle Channel* settings are listed in the positioning section for each joint movement pattern.



Shoulder Extension/Flexion

APPENDIX I

TRAINING INFORMATION

Thankyou for your cooperation in volunteering for this study. You can be sure that your participation in this research will help answer some important questions in the area of isokinetic training. Additionally, you can expect to benefit greatly from the training program. The program has been designed to train your quadricep and hamstring muscle groups which are among the largest in the body.

For those of you unfamiliar with isokinetic training, it is one of the newest and most scientifically advanced methods of training available at present. Unlike other training methods, isokinetics are totally accomodating to changes in muscle force throughout the joint ROM. This is why isokinetics are often referred to as Accommodating Resistance TRaining. The advantage of this is that the muscles being trainind are done so maximally at all points in the ROM. Of course, this will increase the potential for improvements in strength, power and endurance.

Your training program will be;

3 sets of _______ @ 180 degrees/second on Cybex II
or
@ 6 on Orthotron
You are to train your ________ leg only.

Training is to be done on 3 days per week for 6 weeks. It is suggested you train on alternate days. Never train on 3 consecutive days.

The attached sheet explains training times and facilities that are available to students at UW-L. Members at the Cybex Center will use the Orthotron at the Center.

Your cooperation is deeply appreciated in this program. However, I must emphasize the importance of following the exactly. Discrepancies in training will invalidate the research.

I will be available at all times to answer any questions or to help with problems. Feel free to contact me at home.
TELEPHONE
STEPHEN BENDLE