Abstract

BRENNAN, MICHAEL F. The interrelationships among isokinetic strength, power, and muscular endurance in male and female runners and non-runners. M.S. in Adult Fitness/Cardiac Rehabilitation, 1983, 81 p.(N.K.Butts).

Seventy-nine Ss, 38 males and 41 females, were tested on 2 separate occasions for isokinetic strength, power, and muscular endurance on the Cybex II isokinetic dynamometer, Ss were grouped according to sex and weekly running mileage. Nineteen of the males were runners, averaging 43.3 miles/week, and 19 were non-runners. Fourteen females were runners, averaging 34.6 miles/week, and 27 were non-runners. Following an orientation session which involved verbal explanation of the machinery, isokinetic principles, and the test protocol, each S experienced physical practice on the dynamometer. Ss were then tested for strength at 60°/sec., for power at 120, 150, 180, 210, 240, 270, and 300°/sec., and for muscular endurance a 180°/sec. One to 4 days later, this testing procedure was repeated. Dependent t-tests revealed sig (P.<01) increases from T1 to T2 in strength and power in trained males (TM) and trained females (TF) and strength, power and muscular endurance in untrained females. Isokinetic strength and isokinetic power were sig (P.<01) related only in UF r=0.51. It was concluded that an orientation session prior to isokinetic testing was necessary for those having no previous experience with isokinetic instrumentation and/or testing. Also, it was concluded that there is a strong, positive relationship between isokinetic strength and isokinetic power, regardless of training habits. Though statistical sig was achieved in one group between isokinetic strength and isokinetic muscular endurance and isokinetic power and isokinetic muscular endurance, no practical, usable relationships were observed between these parameters in any group.

THE INTERRELATIONSHIPS AMONG ISOKINETIC STRENGTH, POWER, AND MUSCULAR ENDURANCE IN MALE AND FEMALE RUNNERS AND NON-RUNNERS

A Thesis Presented

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Dedication

This work is dedicated to my family, who have always supported me.

Table of Contents

List of Tables

CHAPTER I

INTRODUCTION

Strength, power, and muscular endurance are muscular abilities important to athletic performance. Depending upon the particular skill, a high level of one or more of these abilities may be more important than the others. Also, it is possible that in order to perform optimally in some athletic endeavors, high levels of strength, power, and muscular endurance are needed.

Whatever combination of abilities an athlete needs, it is important that a valid and reliable system can be used to measure these abilities. Also, an understanding of the relationships among these abilities could be tremendously helpful in the development of proper training programs for athletes. For example, if a strong relationship were found between strength and power, it seems logical that undertaking a program of strength training would increase a person's power as well as his or her strength. The same logic could be applied to the relationships between strength and muscular endurance and power and muscular endurance.

Current research involving the relationships among strength, power, and muscular endurance is inconclusive. Many studies have been undertaken with the goal of substantiating these relationships. However, disagreement among findings has left the question about these relationships unanswered.

Travers and Campbell (1974) and Wilmore (1976), among others found a strong positive relationship between strength and power. Conversely, Edgerton (1976) and Counsilman (1977) concluded that since strength training inhibits speed, a critical component of power, their relationship, if any, would be negative.

Wilmore (1976) and Clarke and Stull (1970) found that both strength and muscular endurance increased markedly as a result of a strength training program. This finding led them to conclude that the two are strongly positively related. Berger and Harris (1966) and Wilmore, Parr, Vodak, Barstow, Pipes, Ward, and Leslie (1976) reported similar findings.

Edgerton (1976) opposed these views when he found that strength and muscular endurance were not related. He explained that totally different muscle fiber types are essential to the performance of strength and muscular endurance activities. In light of these differences, he reasoned that strength and muscular endurance are not related. Heyward and McCreary (1977) and Noble and McGraw (1973) shared Edgerton's views and reported no relationship between strength and muscular endurance from their findings.

The same trend of disagreement has occurred involving the relationship between power and muscular endurance. DeLateur, Lehmann, and Fordyce (1968), Lyle (1969), and Girardi (1971) found significant, positive relationships between power and muscular endurance. Reporting contrary findings were Edgerton (1976), Heyward (1975), and Thorstensson and Karlsson (1976) who all found no relationship between power and muscular endurance.

Considering the controversy surrounding the relationships among strength, power, and muscular endurance, it is clear that more conclusive evidence is needed to qualify the existence and magnitude of these relationships.

Relatively speaking, isokinetic muscle testing is a new practice. Though numerous studies have been undertaken using isokinetic machinery as the testing device, only one investigated the relationship between two muscular abilities, strength and muscular endurance. Since isokinetic instrumentation can measure muscular ability at the muscle's strongest point, it seems that properly calibrated isokinetic machinery can provide accurate information concerning peak muscular performance and therefore, strength, power, and muscular endurance interrelationships can be determined.

It has been suggested that valid, reliable results using isokinetic machinery can be obtained only if an orientation session is administered to subjects prior to testing (Coyle, Costill, & Lesmes, 1979; Johnson & Siegal, 1978). These researchers believed that since isokinetic testing is a relatively new practice and unfamiliar to most people, a familiarization session prior to testing would reduce learning during the test and therefore, would increase the reliability of test scores.

Though the rationale behind the orientation session seems logical, the majority of the studies using isokinetic test instrumentation either have not made use of this procedure or have just not reported the use of it in their study. The validity and reliability of their test scores are only assumed. However, in order to accept the necessity and effectiveness of an orientation session prior to isokinetic testing, more study is needed.

Statement of the Problem

There is a lack of conclusive evidence concerning the relationships among strength, power, and muscular endurance. There is even less information involving these relationships using isokinetic instrumentation. In addition, more information is needed concerning the necessity and effectiveness of an orientation session prior to isokinetic testing.

Need for the Study

Having accurate muscular ability measurements and understanding the relationships between strength, power, and muscular endurance and how these parameters are affected by training can give the athlete, coach, and physical educator valuable information upon which to develop a conditioning program which would be specific to an athlete's needs.

Also, more information is needed concerning the orientation procedure prior to isokinetic testing. If the necessity and effectiveness of this procedure can be determined, isokinetic test protocols can be more uniform and test results would be more accurate and comparable.

In light of the above needs, this thesis has been undertaken with the hope of furthering knowledge of isokinetic muscle testing. Specifically, it is intended that a greater understanding of the relationships among isokinetic strength, power, and muscular endurance can be gained. Also, it is hoped that more information as to the necessity and effectiveness of an orientation session prior to isokinetic testing can be gained.

Assumptions

1) The knee extensors of each subject's dominant leg

were tested. This assumed that this particular muscle group accurately represented each subject's strength, power, and muscular endurance.

2) It was assumed that all subjects were at full strength mentally and physically for both tests which allowed them to perform maximally.

3) Due to its malfunction, the single-channel recorder was replaced with a dual-channel recorder for the last one-third of testing. It was assumed that the change in instrumentation did not affect the results.

4) It was assumed that the rest period of four to five minutes between the power and muscular endurance tests was of adequate duration to prevent fatigue from affecting the muscular endurance test scores.

5) Due to the availability of facilities and test instrumentation, subjects were tested at different time intervals. It was assumed that the varying rest periods between tests (one to four days) did not have an effect upon the results.

Delimitations

1) The test sample was not randomly selected. Therefore, any inferences made outside of this test sample may not be warranted.

2) All testing done in this investigation was done with subjects performing isokinetic movements. Therefore,

any relationships found were reported as isokinetic relationships.

Definition of Terms

Torque: the greatest amount of force produced during one isokinetic contraction on the isokinetic dynamometer.

Isokinetic Contraction: accommodating resistance to a contracting muscle with the contractile speed remaining constant throughout the full range of motion.

Full Range of Motion: contraction of the knee extensors from a 90° angle of the knee at rest to a 180° angle of the knee in complete flexion.

Dominant Leg: the preferred leg for coordination and strength activities; chosen by the subject.

Isokinetic Strength: the greatest amount of force that the knee extensors of the dominant leg can produce at the slow contractile velocity of 60°/second.

Isokinetic Power: the greatest amount of force per second that the knee extensors of the dominant leg can produce through one isokinetic contraction at any one of the fast contractile velocities of 120°/sec., 150°/sec., 180°/sec., 210°/sec., 240°/sec., 270°/sec., or 300°/sec.

Isokinetic Muscular Endurance: the percent decline in strength of the knee extensors of the dominant leg after 40 repeated, maximal isokinetic contractions at the fast contractile velocity of 180°/sec.

Runner: a person who has run at least 30 miles per week for the period of at least one month.

Non-Runner: a person who has run less than three miles per week for at least three months.

Cybex II Isokinetic Dynamometer: a resistance machine which maintains a constant speed throughout the full range of motion and accomodates to the amount of muscular force applied to its input shaft (see Appendix A).

Cybex II Chart Recorder: an instrument which prints out on paper the amount of torque produced during an isokinetic contraction (see Appendix B).

Cybex II Chart Data Card: a device which measures recorded torque and equates the torque with foot-pounds.

Hypotheses

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

1. There was no significant differences between the first and second tests in male runners.

2. There was no significant difference between the first and second tests in male runners.
3. There was no significant difference between the first and second tests in female runners.
4. There was no significant difference between the first and second tests in female non-runners.
5. There was no relationship between isokinetic strength and isokinetic power in male runners.
6. There was no relationship between isokinetic strength and isokinetic power in male non-runners.
7. There was no relationship between isokinetic strength and isokinetic power in female runners.
8. There was no relationship between isokinetic strength and isokinetic power in female non-runners.
9. There was no relationship between isokinetic strength and isokinetic muscular endurance in male runners.
10. There was no relationship between isokinetic strength and isokinetic muscular endurance in male non-runners.
11. There was no relationship between isokinetic strength and isokinetic muscular endurance in female runners.
12. There was no relationship between isokinetic strength and isokinetic muscular endurance in female non-runners.
13. There was no relationship between isokinetic power and isokinetic muscular endurance in male runners.

14. There was no relationship between isokinetic power and isokinetic muscular endurance in male non-runners.
15. There was no relationship between isokinetic power and isokinetic muscular endurance in female runners.
16. There was no relationship between isokinetic power and isokinetic muscular endurance in female non-runners.

CHAPTER II

A REVIEW OF RELATED LITERATURE

Introduction

Conventionally, muscular testing for research purposes has been done either isotonically or isometrically. Isokinetic muscle testing, being commonly employed only within the past five years, has not been thoroughly researched.

Throughout the past thirty years, many studies have been reported investigating the relationships among strength, power, and muscular endurance. However, in all of these studies, with the exception of one, muscle testing was done either isotonically or isometrically.

In the last five years, the use of isokinetic movement and isokinetic testing instrumentation for research purposes has become quite popular. However, only one of these isokinetic studies investigated one or all of the relationships among isokinetic strength, power, and muscular endurance (Barnes, 1980)

This review will attempt to define isokinetic muscle testing and summarize studies in which isokinetic movement and isokinetic testing instrumentation were employed.

Isokinetic Testing

Isotonic muscle testing involves the contraction of a muscle using a fixed resistance with a variable speed of shortening. In isometric muscle testing, a fixed resistance is used with no movement of the muscle occurring. Both of these types of muscular contraction have identifiable weaknesses when they are used for research purposes.

The strength of a muscle varies throughout its contraction. It is stronger at some points in the range of motion than at other points, depending upon the angle of the joint. Therefore, the ability of a muscle to move a fixed resistance through a full range of motion is dependent upon the strength of the muscle at its weakest point. Consequently, through an isotonic contraction, only the strength of the muscle at its weakest point can be measured. The muscle's maximum strength cannot be determined.

Isometric muscle testing is limited by the lack of movement in this type of exercise. In isometric exercise, the strength of the muscle can be tested only at the joint angle at which it is contracting. In order to determine maximum strength, the muscle would have to be tested at multiple joint angles.

Isokinetic exercise, first explained by Perrine (1968) and followed up in greater detail by Moffroid, Whipple, Hofkosh, Lowman, and Thistle (1969), is defined as movement through the full range of motion with a constant speed and varying (accommodating) maximal resistance to the muscle at all angles of shortening.

Presently, the most often used and most reliable and valid isokinetic testing instrument is the Cybex II isokinetic dynamometer (Cybex, Lumex, Inc., Bay Shore, NY). Moffroid et al. (1969) found the properly calibrated Cybex II isokinetic dynamometer reliable and valid when tested for accuracy of speed control and torque measurement. A correlation of 0.99 was found between pre-set dynamometer speed and actual speed of the input shaft while in motion. A correlation of 0.99 was found between the torque output printed on the chart recorder paper and the measured angular force production. Coyle, et al. (1979) found correlation of 0.95 for validity in measuring force and 0.98 for reliability of score reproduction. However, Coyle et al. (1979) qualified their findings by insisting that valid, reliable results using the Cybex II can only be obtained if the proper pre-test orientation procedure is carried out. In agreement with this claim were Johnson and Siegal (1978), who observed that accurate, consistent scores on the Cybex II can be obtained only after practice on the Cybex II prior to test day. In addition, they cited warm-up contractions at fast and slow speeds immediately preceding actual testing as necessary in obtaining accurate, consistent results. Based on the findings of these researchers, the properly calibrated Cybex II isokinetic dynamometer has been seen as a valid, reliable muscle testing instrument if a subject has been properly orientated to it.

As previously pointed out, the speed of contraction in an isokinetic movement remains constant throughout the range of motion while the resistance to the muscle changes, or accommodates to match the changing muscular output during shortening. Consequently, in an isokinetic contraction, the resistance the muscle can move is not limited to the strength of the muscle at its weakest point. At the muscle's weakest point, the muscular output will be low; and therefore, the resistance accommodates accordingly. At the muscle's strongest point, the resistance accommodates to resist the muscle to its highest potential.

Isokinetic Testing of Leg Extensors

During dynamic contraction muscular force generated by the knee extensors causes extension of the knee. The lower leg, strapped to the input shaft exerts a force which is transmitted to the inside of the dynamometer to a load cell. This electronic cell has two functions: to instantly load the dynamometer input shaft with a resistance equal to the muscular output, and to send this muscular output information to the chart recorder. (Katch, McArdle, Pechar & Perrine, 1974).

Since maximal muscular output can be measured on the Cybex II isokinetic dynamometer, this method of muscle testing seems to be the most efficient (Halling & Dooley, 1979).

Additional advantages to using the Cybex II in muscle testing include easy detection of submaximal efforts and the reduced risk of injury through muscular contraction. Submaximal efforts can be detected by observing the different sized and shaped torque curves printed on the chart recorder. The risk of injury during contraction on the Cybex II as opposed to lifting free weights is reduced due to the accommodating nature of isokinetic machinery. If pain is experienced during contraction using resistance weight other than the Cybex II, the person must still lower the resistance, keeping a strain on the source of injury. With the Cybex II, a person experiencing pain can simply stop the contraction since there is no resistance to no output. The input shaft will stop and the person can be taken off the instrumentation and treated (Cybex, Lumex, Inc., Bay Shore, NY).

Since the Cybex II isokinetic dynamometer has been found, under the proper conditions, to be a valid and reliable testing instrument, an increasing number of researchers are using the Cybex II to test strength, power, and muscular endurance.

After Perrine (1968) and Moffroid et al. (1969), Moffroid and Whipple (1970) tested athletic speed and determined at what speed certain athletes should train at on the Cybex II to achieve the greatest training benefits for their skill. Katch et al. (1974) adapted the Cybex II to become part of a bicycle ergometer in order to measure the power of cyclists at different pedaling speeds.

In 1975, Moffroid and Kusiak further defined power and how it can be calculated through the use of an isokinetic dynamometer such as the Cybex II. Soon after that study, Osternig, Bates, and James (1977) tested the power of the knee extensors of college football players on the Cybex II. Pipes and Wilmore (1975) used the Cybex II when they compared strength development in isotonic and isokinetic strength training programs.

Several researchers have found that a person's muscle fiber composition can be accurately predicted according to the rate of fatigue while performing fast (180°/sec.) maximal contractions of the knee extensors on the Cybex II (Tesch & Karlsson, 1978; Tesch, Sjodin, Thorstensson & Karlsson, 1978). Comparing fatigue rates to actual muscle biopsy results, they formulated linear regression equations which can somewhat accurately predict a person's muscle fiber composition.

Lesmes, Coyle, Costill, and Fink (1978) determined that both power and strength could be developed optimally for a skill by training on the Cybex II at a speed which approximates the speed of that skill in competition. Based on their findings, they suggested that there exists somewhat of a relationship between strength and power. Others (Costill, Coyle, Fink, Lesmes & Witzman, 1979; Coyle et al., 1979; Halling & Dooley, 1979; Perrine & Edgerton, 1978) have also used the Cybex II for power assessment.

Anderson, Cote, Coyle, and Roby (1979) compared male and female strength at different speeds and found that men were able to exert more force at faster speeds, and therefore, were capable of greater power than women.

It is obvious that the Cybex II isokinetic dynamometer has been used for a variety of experiments. However, to date, only one study specifically has investigated the interrelationship between two muscular parameters. In this study Barnes (1980) used a test speed of 120°/sec. for both the strength and endurance test. He found that when he defined muscular endurance as the number of repetitions performed in excess of 90% or 75% of peak torque, he found low but significant correlations of 0.36 and 0.27, respectively. He concluded that when muscular endurance is defined as the amount of work done during a work bout, there appears to be a significant, but low, positive correlation between isokinetic strength and isokinetic muscular endurance.

The Relationship of Strength to Muscular Endurance

Findings to date are in disagreement as to the relationship of strength to muscular endurance. Many researchers have found that strength and muscular endurance are closely related since both of these fitness parameters were said to be developed through one type of training. Tuttle, Janney, and Salzano (1955) found that after testing subjects on a dynamometer, those with the greater maximal strength also had a greater amount of muscular endurance. They concluded that there was a definite relationship between strength and muscular endurance. Delateur et al. (1968) and Wilmore (1976) studied the results of a strength training program. Both studies found significant increases in muscular endurance as well as in increases in strength. Again, a relationship between the two was suggested.

After a seven week muscular endurance training program, Clark and Stull (1970) found a significant increase in strength and muscular endurance, and concluded that the two are positively related. Berger and Harris, in Clarke (1974) did a study in which they had subjects develop different levels of strength and then tested each for muscular endurance. They found that the strongest people had the greatest amount of muscular endurance, signifying a close relationship between the two. Clarke (1973) tested subjects after they participated in a strength training program and found significant strength and muscular endurance increases and a 0.90 correlation between the two. Wilmore, et al (1976) also concluded that since strength and muscular endurance both were developed via a muscular endurance training program, there must be a relationship between the two.

Kearney (1977) stated that since overall neuromuscular efficiency increases as a result of either strength or muscular endurance training, both can be enhanced through the same method of training. He suggested that a relationship exists between the two.

A seemingly equal number of studies have concluded that there is little or no relationship between strength and muscular endurance. In opposition to Kearney's findings are Edington and Edgerton (1976) who reported that totally different physiological adaptations arise from strength as opposed to muscular endurance training. From muscular endurance training, they found adaptations such as, increased capillarization around the muscle, increases in mitochondrial size and number, increased oxidative capacity through increased enzyme activity, and increased fatty acid oxidation and usage of energy. From a strength training program, they found increases in the amount and efficiency of myofibrillar proteins and contractile mechanism, and increased production and usage of phosphofructokinase, an enzyme necessary in anaerobic ATP breakdown. They reasoned that since totally different physiological adaptations take place from different training programs which cannot enhance one another, either strength or muscular endurance can be developed from one type of training program, not both. Sharing this same opinion were Heyward and McCreary (1977) who studied strength and muscular endurance and reached the same conclusion based on differences in muscular physiological changes resulting from each program.

DeLorme (1945), who set the groundwork for strength training, stated that because strength training, which involves low repetition, high resistance, and endurance training, which involves high repetition, low resistance, are totally different methods of exercise, neither method is capable of producing gains in both areas.

Some researchers have agreed with Edington and Edgerton (1976), Heyward and McCreary (1877), and DeLorme (1945), but not to such an extreme. McGraw and Burnham (1966) noted that though one may benefit in both strength and muscular endurance through one method of training, neither component will be developed significantly. Counsilman (1977), citing the physiological adaptations that take place as a result of strength and muscular endurance training programs, claimed that both strength and muscular endurance can be developed from one type of training but to a minimal extent. He suggested that training be specific to the desired goal in order to achieve the greatest results.

Noble and McGraw (1973) studied different methods of strength and muscular endurance development and concluded that there is no relationship between the two. A strength gain, for example, is independent of a muscular endurance gain.

The Relationship of Strength to Power

Findings of studies investigating the relationship between strength and power favor a relatively strong, positive relationship. However, there once again is disagreement as to their relationship.

As far back as 1950, Capen found that through a strength training program, power, as well as strength, improved significantly. On this basis, he claimed a close relationship between the two. Masley (1955) did a similar experiment and obtained the same results. He also claimed a close relationship between strength and power. Others (Bergeron, 1966; Clarke & Henry, 1961; DeLateur et al., 1968; Girardi, 1971; Lagasse, 1970; Lyle, 1969; Travers & Campbell, 1974; Whitley & Smith, 1966; Wilmore, 1976) were of the philosophy that because strength and power could both be improved via strength training, they must be related. The feeling among these researchers was that since power is dependent upon strength, an increase in strength will obviously increase power potential.

Astrand and Rodahl (1977), Coyle et al. (1979), Hickson (1980), Lesmes et al. (1978), Tesch et al. (1978), Thorstensson, Grimby & Karlsson (1976), and Thorstensson and Karlsson (1976) all found that since strength and power movements are dependent upon similar muscular qualities, they are positively related. An increase in one causes an increase in the other.

Some researchers, after testing for power and strength, have reported high correlations between the two. Nelson and Fahrney (1965) found a correlation of 0.76 between strength and speed of movement in college-age males. Also finding a high correlation was Henderson (1963) when he reported a correlation of 0.71 between dynamic leg strength and leg power in college-age males. Berger and Blaschke (1967) also studied leg strength and leg power and found a significant relationship ($r = 0.569$ $p < .01$).

In the early 1950's, the question arose as to the possibility of strength increases slowing movement and therefore, causing a simultaneous decrease in power. Chui (1950) investigated this possibility and found it to be untrue. He tested weight lifters and non-lifters and found that the weight lifters, who were stronger, could produce more power than the non-lifters. Since then, however, evidence has been compiled which indicates that strength development may inhibit power output. Clarke and Henry (1961) and Smith and Whitley (1965) suggested that neuromuscular adaptation to specific exercise, for example slow, strength training, would inhibit speed, the other component of power. In agreement with these findings were Osternig et al. (1977) and Pipes (1979), who tested subjects for strength and found an inverse relationship with power. Development of one inhibited the development of the other.

Others (Blucker, 1965; Mendryk, 1966) have found strength training to have no effect on power. They claimed that an increase in strength will not affect power either way. Compromising approaches were taken by Karvinen and Komi (1974) and Sharkey (1979). Both of these studies indicated that training at fast speeds with resistance between 30 - 60% of maximum strength will produce gains in power and strength, though neither will gain optimally. Although research favors a strong, positive relationship between strength and power, it is evident that there is still some doubt concerning their closeness.

The Relationship of Power to Muscular Endurance

Many have found that muscular endurance correlates highly with power. Capen (1950) tested the effects of strength training on strength, power, and muscular endurance. He found that all three significantly improved as a result of strength training and concluded that all three are positively related. Masley et al. (1955) did a study similar to Capen's and found the same results; that strength, power, and muscular endurance all improved significantly from a program of strength training. They too claimed a positive relationship between the three. DeLateur et al. (1968) found that power, as well as muscular endurance, increased significantly as a result of a muscular endurance training program. From their findings, they concluded that power and muscular endurance are closely related.

Lyle (1969) reversed the norm by looking at the effects of a power development program. He found that the development of power significantly increased muscular endurance as well as power. On this basis, Lyle reported a positive relationship between power and muscular endurance. Girardi (1971) studied the effects of three different training programs (isotonic, isokinetic, isometric) which were designed to develop strength and muscular endurance. He found that all three programs significantly improved power and muscular endurance and concluded that the two fitness components are positively related.

Counsilman (1977), Edgerton (1976), and Heyward and McCreary (1977) found that as a result of power development, the explosive, easily recruitable, fast fibers are trained. Through muscular endurance training, the slow, fatigue-resistant fibers are trained. These researchers found that both of these fiber types cannot be trained by one method of exercise. Therefore, they concluded that power and muscular endurance cannot be developed from the same type of training, which suggests little or no relationship between the two.

Muscular Ability Measurements in Females

Several investigators have studied the differences in muscular ability between males and females (Anderson et al. 1979; Lauback, 1976; Stauffer, 1976). These researchers concluded that males are generally stronger than females in upper-body, trunk, and lower-body strength. In addition, both Anderson et al. (1979) and Stauffer (1976) found men to be capable of producing more power than females. In these studies, both strength and power were tested isokinetically with the Cybex II. Perrine and Edgerton (1978) used the Cybex II to study force-velocity and power-velocity relationships in male and female volunteers. They found that as speed of movement is increased, isokinetic strength diminishes.

Summary

It is obvious that the relationships among strength, power, and muscular endurance have been studied quite extensively with no final agreement as to their closeness. The vast majority of these studies have been done using isotonic or isometric movements. While the popularity of isokinetic testing with the Cybex II isokinetic dynamometer is growing, only one study has been done using this testing mode to determine the relationships among strength, power, and muscular endurance. This isokinetic study, along with most of the isotonic and isometric studies, used male subjects. However, at this point, there is little information on either females or males concerning the relationships among isokinetic strength, power, and muscular endurance and if these relationships are affected by endurance training (running).

CHAPTER III

METHODS

Introduction

The intention of this study was to determine the relationships among isokinetic strength, power, and muscular endurance. In addition, an orientation session was administered prior to testing to determine the necessity and effectiveness of this procedure in producing valid and reliable test results.

Subject Characteristics and Setting

Thirty-eight males and forty-one females, most of them students at the University of Wisconsin - LaCrosse, volunteered for the study. Of the males, 19 were runners and 19 were non-runners. In the male group, runners averaged 70.2 inches, 151.7 pounds, and were maintaining 43.3 miles/week. The non-runners averaged 70.8 inches, 171.9 pounds, and were maintaining 1.1 miles/week. In the female group, the runners averaged 64.6 inches, 121.5 pounds, and were maintaining 34.6 miles/week. The non-runners averaged 63.1 inches, 126.6 pounds, and were maintaining 2.6 miles/week. Subject age ranged from 18 to 30 years with a mean age of 23. Testing was carried out in the Physical Therapy Department's Clinical Science

Laboratory in Cowley Hall at the University of Wisconsin - LaCrosse. Informed consent forms (see Appendix C) and subject information forms (see Appendix D) were completed by each subject prior to the orientation session. If a subject was found to be not at full strength, either through conservation or via the subject information sheet, he or she was disqualified from the study.

Materials and Equipment

The following items manufactured by Cybex, Lumex, Inc., Bay Shore, New York, were used for testing purposes in this study: the Cybex II isokinetic dynamometer, S-H-D double width exercise table, dynamometer speed selector, single-channel recorder, dual-channel recorder, chart data card, long input adapter with shin pad and velcro strap, calibration T-bar, and two spacer pads. Additional equipment included a spring scale, tape measure, 70 pounds of weight in 25, 10, 5, and 2.5 pound discs, and a small screwdriver.

Orientation and Test Procedure

Prior to the actual test day, all subjects participated in an orientation procedure. This procedure included two parts. The first part was an explanation of isokinetic exercise, the principles of the isokinetic dynamometer, and the test protocol which was to be used. The importance of maximal exertion was stressed. Following the explanation of the machinery and test protocol, the subject's dominant leg was determined by asking which leg they would normally use to kick a football or soccer ball.

The second part of the orientation session involved the physical. After proper calibration of the Cybex II (see Appendix E), the subject was positioned in the test chair (see Appendix F) and was instructed to perform practice contractions at different speeds on the dynamometer. After this practice, the actual test protocol was undertaken and completed. For the test, the subject was instructed to perform three maximal contractions of the knee extensors at each test speed. After each change of speed, the tester gave a cue for the subject to begin the next three contractions. Approximately five seconds elapsed between sets of contractions. Speeds used in the test protocol included: 60°/sec., 120°/sec., 150°/sec., 180°/sec., 210°/sec., 240°/sec., 270°/sec., and 300°/sec.

Following these tests a rest period of four to five minutes was given while the muscular endurance test protocol was explained. The endurance test called for 40 maximum contractions of the knee extensors of the dominant leg to bring the knee to a 180° angle followed by the relaxation of the knee extensors to allow the knee to return to a resting position (90° angle).

Upon completion of the endurance test, subjects were encouraged to ask questions to clear up any problems or misunderstandings they might have had concerning the machinery or test protocol. Subjects were then rescheduled for testing at their earliest convenience. Time between tests ranged from one to four days.

When a subject returned for the second time, he or she was positioned in the chair correctly, secured, and was instructed to perform warm-up contractions at slow, intermediate, and fast speeds. Following the warm-up, the test protocol was reviewed. If no questions were asked, the test protocol was begun. The test protocol followed the first day test protocol exactly.

Strength Scoring

A sub'ect's strength was determined by calculating the greatest amount of force that he or she was capable of producing at the slow contractile velocity of 60°/sec. The greatest amount of torque deflected on the chart recorder was converted to foot-pounds using the chart data card.

Power Scoring

A subject's greatest power was determined by calculating the amount of power he or she was capable of producing at each test speed (see Appendix G). A subject's greatest power score, regardless of the speed at which it was achieved, was called his or her maximum power production in foot-pounds/second.

For determination of maximum power, multiple speed testing was used since individuals vary in the speed at which they produce their maximum power. This variation is dependent upon the muscle fiber compostion of each person's knee extensors (Coyle et al., 1979; Edgerton, 1976; Halling & Dolley, 1979; Lesmes et al., 1978). In order to minimize the chance of missing the speed at which an individual was able to produce his or her maximum power, multiple-speed testing was used.

Muscular Endurance Scoring

A subject's muscular endurance was determined by calculating the percent decline in strength from the beginning of the muscular endurance test to the end. The strength of the subject's first three contractions was averaged to give an initial strength score. The strength of the subject's final three contractions was averaged to yield a final strength score. The percent change from initial strength to final strength was recognized as a subject's muscular endurance score (see Appendix H). Throughout all testing, verbal encouragement was employed for the purpose of motivating each subject to perform maximally.

Statistical Analysis

Standard statistical methods were employed in the data analysis. Dependent t-tests were used to determine significant differences between the first and second tests the trained male, untrained male, trained female, and untrained female groups. Significant differences were accepted at the .05 level.

To determine the relationships between isokinetic strength, power, and muscular endurance, correlation coefficients were established between those variables in the following groups: male runners, male non-runners, female runners, female non-runners, total males, total females, total runners, total non-runners, and total N. If a correlation coefficient in any group was found to be significant at the .05 level, bivariate linear regression was used to determine the predictability of one variable to another. To determine the strength of predictability, the standard errors of the estimate and coefficients of determination were reported for each equation.

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

An objective of this study was to determine the necessity of an orientation prior to isokinetic testing. Subjects were tested on two separate occasions for strength, power, and muscular endurance on the isokinetic dynamometer. Following these tests, dependent t-tests were calculated to determine the significance of differences between the first and second tests.

Another objective of this study was to address the questions of the relationships among isokinetic strength, power, and muscular endurance and the effect of running training upon these relationships. Correlation coefficients were determined from the subject's second test scores between strength and power, strength and muscular endurance, and power and muscular endurance. From this and additional statistical treatment of the data, relationships, the strength of those relationships, and the standard errors were determined.

The testing instrument employed in this study, the Cybex II isokinetic dynamometer, was arranged to test the knee extensor muscles of each subject. The dynamometer was positioned individually to each subject according to his or her leg length, body size, and leg dominance (see Appendix F). Tests for strength, power, and muscular endurance were done in succession with approximately five minute rest between the power and muscular endurance tests.

Seventy-nine subjects, thirty-eight males and forty-one females, most of them students at the University of Wisconsin - LaCrosse, were tested for strength, power, and muscular endurance on two separate occasions. Each sex was subgrouped into either a running group or non-running group according to the number of miles per week that they had been running consistently. Within the male group, nineteen were runners and nineteen were non-runners. Within the female group, fourteen were runners and twenty-seven were non-runners.

Orientation Session

Regardless of a subject's prior experience with isokinetic machinery, it was assumed that none had had experience nor was familiar with this type of machinery. Following the explanation of isokinetic principles, the isokinetic dynamometer, and the test protocol, each subject was tested for strength, power, and muscular endurance. Each subject's strength, power, and muscular endurance scores were calculated and recorded. Within the next three days, the subject returned and was retested.

Table 1 illustrates the significant difference between the first and second tests. Male runners showed a significant (P .001) increase in strength scores from the first to the second test. Similarly, both the female runners and the female non-runners showed significant (P<.01) increases in strength scores on the second test. Since the majority of subjects in the running male, running female, and non-running female groups had had no prior experience with isokinetic instrumentation, the orientation session was effective and necessary in reducing learning during the second test and increasing the reliability of test scores.

In one group, male non-runners, no significant difference was seen in strength scores between tests. It is theorized that since many of the subjects in this group had admitted to previous resistance training, which included the use of isokinetic machinery, any knowledge acquired from the orientation session was not of great enough magnitude to elicit a significant change from first to the second test.

Concerning power, the male runners and female non-runners showed significant (P<.001) increases between power scores as did the female runners (P<.01). These subjects' lack of experience with isokinetic instrumentation was seen as the important factor in the difference. For these subjects, the orientation session once again was seen as effective and necessary.

Table 1.

Means and Standard Deviations of
The First and Second Tests

	Strength (ft. lbs.)		Power (ft. lbs./sec.)		Muscular Endurance (% decline)	
	T1	T2	T1	T2	T1	T2
Running Males (N = 19)	117.26[a] 22.46[b]	134.21* 26.53	112.75 25.87	141.40* 45.08	68.66 13.46	65.88 9.63
Non-Running Males (N = 19)	151.42 38.83	149.47 30.17	152.79 43.51	153.39 31.26	80.26 13.59	77.92 14.04
Running Females (N = 14)	64.57 20.99	80.07** 19.59	56.03 22.86	79.43** 27.23	75.89 14.59	69.70 9.04
Non-Running Females (N = 27)	73.93 25.77	87.41** 29.98	67.25 26.89	99.50* 34.79	79.69 19.23	72.94** 13.61

a = mean
b = standard deviation

* significant at P<.001 level
** significant at P<.01 level

Technical Note: Concerning a person's muscular endurance score, the lower the % decline, the greater the muscular endurance.

Comparing muscular endurance test scores, the non-running female group showed a significant difference ($P<.01$) between the first and second tests. Once again, the lack of experience combined with the knowledge and practice gained during the orientation session was seen as the reason for the difference. These findings are in agreement with those of Coyle et al. (1979) and Johnson and Siegal (1978), who also reported that consistent results were not seen unless subjects were familiar with the isokinetic machinery.

In the other three groups differences were observed but were not statistically significant ($P<.05$). The reason for the lack of a significant difference between scores in the non-running male group may be explained by this group's experience with resistance exercise and isokinetics. In the two running groups, the lack of difference between muscular endurance tests may be explained by these subjects training in muscular endurance activity. Since the members of both of these groups were trained endurance athletes, they were quite familiar with continuous activity. Since the muscular endurance test was a continuous activity, it was theorized that these endurance athletes were comfortable with and competent in this activity following the verbal explanation before the first test, which would reduce learning from the first test. This phenomenon could have made the difference between tests smaller.

From the findings of this study, it can be concluded that the effectiveness and necessity of an orientation session prior to testing with isokinetic instrumentation seems to be dependent upon the type of subjects being tested. If the subjects have had experience in muscular resistance activity, which included isokinetic resistance, reliable test scores can be obtained following a verbal explanation and review of machinery and test protocol. It seems that the more experience a person has had with isokinetic movement and instrumentation, the less explanation and practice may be needed in order to produce reliable results.

Also, it is possible that if a person has had previous experience in an activity similar to the test protocol, test results obtained from that person may be reliable after only a verbal explanation. This phenomenon is illustrated by the trained male and trained female groups in the muscular endurance test. Since there were no significant differences between the first and second tests, it is hypothesized that these subjects' familiarity with and competence in muscular endurance activity allowed them to perform maximally in the first test, without a practice session.

Importantly, the results show that with those that have had no previous experience with isokinetics, an orientation session including verbal explanation and a practice session is effective and necessary. According to

Coyle et al. (1979) and Johnson and Siegal (1978), test scores following this procedure are more reliable. It should be noted in Table 1 that with the exception of the male non-runners, all scores improved the second day.

Based on the above findings, hypothesis 1, 3, and 4 were rejected. Significant differences between the first and second tests were seen in male runners, female runners, and female non-runners. Since no difference was seen between tests in male non-runners, hypothesis 2 was accepted.

The Relationship Between Isokinetic Strength and Isokinetic Power

Strength can be defined as the amount of force that can be produced with one maximal effort (Fox & Matthews, 1981). Power can be defined as force production per unit time (Matthews & Fox, 1976). From these definitions it can be deduced that power potential is dependent upon the amount of strength one possesses. Several researchers (Travers et al., 1974; Wilmore, 1976; Whitley & Smith, 1976) found that power can be increased via an increase in strength. Based on their findings, and the fact that power is dependent upon strength, these researchers concluded that there exists a strong, positive relationship between strength and power.

Table 2 illustrates the correlation coefficients calculated between isokinetic strength and power. It can be observed that in all groups, positive, significant relationships were found between these two variables in all groups.

It has been theorized that muscle fiber adaptations to training are specific to the type of exercise undertaken (Astrand & Rodahl, 1977; Coyle et al., 1979; Hickson, 1980; Lesmes, Coyle, Costill & Fink, 1978; Tesch et al., 1977; Thorstensson et al., 1976; Thorstensson & Karlsson, 1976). These researchers found that muscular adaptations resulting from strength training include increases in adenosine triphosphate (ATP), phosphocreatine (PC), and myofibrillar ATPase, an enzyme necessary for ATP breakdown and resynthesis. In addition, they also found increases in glycogenolytic enzyme activity, a greater rate of calcium release and uptake in the sarcoplasmic reticulum, and a larger cross-sectional area of fast twitch fibers. These adaptations help to increase the speed and force of contraction and the rate at which the muscle develops tension. Therefore, a muscle is able to develop tension more quickly followed by a faster, more forceful contraction, enhancing both strength and power movements. It would seem logical that there is a positive relationship between strength and power.

The aforementioned researchers found that a person who trained for strength is subjecting their muscle to the physiological adaptations described above. With the increased contractile ability of the muscle, a person would have the ability to exert greater force in one contraction and would be able to produce that force in less time, hence, gains in strength and power. Consequently, a very strong person should be capable of producing a proportionally high amount of power. Looking at Table 2, it can be seen that in all groups, isokinetic strength and power were highly related in all groups. This finding is in agreement with those researchers discussed previously who believed that strength and power are positively related.

Since the correlation coefficients determined between isokinetic strength and power were high in all groups, then the predictably of one variable from another was fairly accurate as judged from the standard error of the estimate (SEE). For example, in the male non-runners' group, a strength score inserted into the regression equation for that group will yield a power score that will fall within ±15.31 foot-pounds/second of the actual measured power score. The coefficient of determination (r^2) represents the amount of variance in predicting one variable from the other. For example, in the male non-runners' group, the prediction of power from strength will be 58% accurate.

On the basis of the findings that isokinetic strength and isokinetic power were found to be significantly ($P<.01$)

Table 2

Correlation Coefficients, Regression Equations, and Predictability of Isokinetic Power from Isokinetic Strength

	r	r^2	SY.X ft.- lbs/sec.	Regression Equation
Male Runners	0.82*	0.67	25.91	Power = -44.8 + 1.4(strength)
Male Non-Runners	0.72*	0.58	15.31	Power = 45.52 +.742(strength)
Female Runners	0.84*	0.71	14.66	Power =-14.52 +1.17(strength)
Female Non-Runners	0.90*	0.81	15.17	Power = -6.42 +1.16(strength)
Total Males	0.76*	0.58	25.11	Power = 4.09 +1.01(strength)
Total Females	0.89*	0.80	15.09	Power = 11.46 +1.19(strength)
Total Runners	0.89*	0.80	22.02	Power =-20.89 +1.22(strength)
Total Non-Runners	0.90*	0.81	18.55	Power = 11.79 +.995(strength)
Total N	0.89*	0.80	20.57	Power = -.667 +1.05(strength)

*Significant at $P<.01$ level

related in all groups hypotheses 5, 6, 7, and 8 were rejected.

The Relationship of Isokinetic Strength to Isokinetic Muscular Endurance

Strength can be defined as the amount of force in one maximal exertion while muscular endurance can be defined as the ability of a muscle to contract repeatedly against a submaximal load over a period of time (Fox & Mathews, 1981). These two parameters have different definitions and very different muscular mechanisms behind them. As previously pointed out, the amount of strength a person is capable of depends upon his or her muscular make-up. This is also true of a person's muscular endurance ability, but the muscular qualities necessary to muscular endurance differ vastly from those muscular qualities needed for strength.

While strength depends upon the ability of the muscle to contract forcefully, recruiting as many fibers as possible, muscular endurance depends upon the ability of the muscle to contract repeatedly, alternating the use of the fibers in the muscle.

Heyward (1975), Holloszy and Booth (1976), and Thorstensson and Karlsson (1976) found that muscular adaptations resulting from a muscular endurance training program include an increased mitochondrial concentration and increased mitochondrial enzyme activity in the sarcomere, an increased capacity for the muscle to generate ATP aerobically, and an increase in myoglobin stores. All of these adaptations enhance the muscle's ability to use oxygen to generate energy.

The findings of Edgerton (1976) were in agreement with the above findings. He also reported that following a muscular endurance training program, the fibers were capable of less tension output at a slower rate of contraction, and were relatively fatigue-resistant. He also found that an increased vascularity within the muscle allowed for the deliverance of more oxygenated blood to the muscle.

All of the findings cited above indicate that following a muscular endurance training program, a muscle, due to its increased oxidative capacity, is more capable of resisting fatigue and therefore, can contract repeatedly for a longer period of time. Also, a training program of this type increases the muscle's time to peak tension, and reduces the force and speed of contraction.

It is obvious that the muscular qualities necessary for strength activities differ greatly from those needed for muscular endurance activities. For this reason, and due to the findings of this study illustrated in Table 3, it can be concluded that there is a weak relationship between isokinetic strength and isokinetic muscular endurance.

Though positive correlations were found in the male runners group ($r = 0.33$) and in the total male group ($r = 0.22$), neither relationship was significant ($P < .05$).

Table 3

Correlation Coefficients, Regression Equations and Predictability of Isokinetic Muscular Endurance From Isokinetic Strength

	r	r^2	SY.X % Decline	Regression Equation
Male Runners	0.33	0.11	62.15	
Male Non-Runners	0.02	0.0004	77.90	
Female Runners	-0.24	0.06	67.58	
Female Non-Runners	-0.39*	0.15	67.25	M. Endurance=91.25 + .195 (strength)
Total Males	-0.22	0.05	70.08	
Total Females	-0.32*	0.10	67.66	M. Endurance=85.56 - .153 (strength)
Total Runners	-0.06	0.0036	67.67	
Total Non-Runners	-0.04	0.0016	75.37	
Total N	-0.02	0.0004	71.60	

*Significant at P<.05 Level

In the male non-running group, the relationship was nearly non-exi tent (r = 0.02). Similar results were observed in the total running group (r = 0.06), and the total non-running group (r = -0.04), and in the total group (r = -0.02). The absence of any relationship between isokinetic strength and isokinetic strength and isokinetic muscular endurance can be explained by the differences in muscular qualities needed for each parameter. These findings are in agreement with those of Barnes (1980), who obtained correlation coefficients of -0.03 and 0.04 when he compared isokinetic strength to isokinetic muscular endurance in 23-year-old males.

Further evidence of the weak relationships found between isokinetic strength and muscular endurance is seen in the SEE and r^2 in Table 2. The r^2, an indicator of predictive ability, is very low in all cases. The SEE, representing the limits of error in predicted muscular endurance as opposed to actual measured muscular endurance, is very high.

These two measurements indicate that if a strength score were inserted into a regression equation for that group, the predicted muscular endurance score would be very inaccurate.

Significant negative relationships between strength and muscular endurance ($P < .05$) were found in the female non-running group (r = -0.39) and in the total female group ($r = -0.32$). Also, a negative but nonsignificant ($P < .05$) relationship was observed in the trained female group ($r = -0.24$). These findings indicate that the stronger a female is, the less muscular endurance she will have. From these results, it can be theorized that in order to develop both strength and muscular endurance, both males and females must undertake separate training programs. Apparently both cannot be developed from one program. This theory is in agreement with the conclusion of Edington and Edgerton (1976), and Hickson (1980) who claimed that since strength and muscular endurance activities depend upon totally different muscular qualities which cannot enhance one another, either strength or muscular endurance can be developed from one training program, not both.

Based on the findings that in non-running females, there was a significant relationship between isokinetic strength and isokentic muscular endurance, hypothesis 12 was rejected. Since there were no significant ($P < .05$) relationships found in the male runners, male non-runners, or female runners, hypotheses 9, 10, and 11 were accepted.

The Relationship of Isokinetic Power to Isokinetic Muscular Endurance

Power can be defined as the amount of force exerted per unit time which in this study, was one second. Muscular endurance can be defined as the ability of a muscle to contract repeatedly which in this study, was forty times, against a submaximal load, in this study 180°/sec.

Power, needing the same muscular qualities as strength, is very different from muscular endurance, whose necessary muscular qualities have also been outlined. The findings of this study, as illustrated in Table 4 seem to support the theory that since power and muscular endurance require such different muscular qualities, which cannot enhance one another, the two are not closely related.

In Table 4, it can be seen that in the female groups, a relationship was found between isokinetic power and isokinetic muscular endurance. However, in only two of the groups was the relationship significant ($P < .01$). Aside from the non-running male group, in which a very weak, negative relationship was found ($r = -0.15$), male groups showed no relationship between the two, with the running males showing a 0.03 correlation and the total males showing a 0.01 correlation.

In the female groups, all relationships were negative. In both the non-running female group ($r = -0.51$) and the total female group ($r = -0.41$), the relationships were significant ($P < .05$). The running females also showed a moderate, negative relationship ($r = -0.39$) which was nonsignificant ($P < .05$).

It is evident from Table 4 that even in the non-running female and total female groups in which the relationships

Table 4

Correlation Coefficients, Regression Equations, and Predictability of Isokinetic Muscular Endurance from Isokinetic Power

	r	r^2	SY.X % Decline	Regression Equation
Male Runners	0.03	0.0009	65.85	
Male Non-Runners	-0.15	0.02	77.14	
Female Runners	-0.39	0.15	64.26	
Female Non-Runners	-0.51	0.26	62.75	M.Endurance = 92.88 - .196(power)
Total Males	0.01	0.0001	71.90	
Total Females	-0.41*	0.17	64.19	M.Endurance = 86.04 - .151(power)
Total Runners	-0.20	0.04	66.42	
Total Non-Runners	-0.17	0.02	74.67	
Total N	-0.14	0.02	70.89	

*Significant at P<.01 Level

were significant, the predictability of muscular endurance from power was very low. The coefficient of determination (r^2) was very low and standard error of the estimate (SEE) very high. A power score entered into the regression equation for the group would not yield an accurate muscular endurance score.

From the results of this study, it can be concluded that a female possessing a large amount of power will be relatively weaker in the area of muscular endurance. On the other hand, it cannot be predicted from a male's power output how much muscular endurance he is capable of. The differences in the relationships between isokinetic strength and isokinetic muscular endurance and isokinetic power and isokinetic muscular endurance in males and females can be explained by the exercise trend among the subjects in this study. The male subjects, as evidenced from the information sheets, seemed to be more extensively involved in athletics and different types of resistance activities. It is theorized that this variety of activity and muscular resistance activity has allowed some male subjects to develop their muscular qualities both ways, for strength, power and muscular endurance activities. The males that did indeed show a high amount of both strength and muscular endurance or power and muscular endurance could be used as evidence to support this theory. This theory helps to explain that male isokinetic endurance cannot be predicted from either isokinetic strength or isokinetic power since the relationship is so variable.

Based on the findings that in non-running females, a significant ($P < .05$) relationship was observed between isokinetic power and isokinetic muscular endurance, hypothesis 16 was rejected. Since no significant ($P < .05$) relationships were observed in running males, non-running males, and running females, hypotheses 13, 14, and 15 were accepted.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Summary

Following an orientation to isokinetic machinery, which included a verbal explanation and physical practice, the knee extensor muscles of 38 male subjects, 19 runners and 19 non-runners, and 41 female subjects, 14 runners and 27 non-runners, were tested on the Cybex II isokinetic dynamometer for isokinetic strength, power, and muscular endurance. Subjects were tested immediately after the orientation explanation and practice once again one to four days later.

The data collected from the two tests were analyzed to determine the necessity of an orientation session prior to isokinetic testing. Also, scores of isokinetic strength, power, and muscular endurance were studied to determine the interrelationships among them.

The necessity and effectiveness of an orientation session prior to isokinetic testing was found to be dependent upon the subject's previous experience with isokinetic resistance. For the subjects who had previous experience with isokinetic resistance exercise, the orientation session was found to be unnecessary in the production of reliable test scores. However, with

subjects having no previous isokinetic resistance experience, the orientation session was found to be both necessary and effective as significant increases in test scores were observed following the orientation session. In addition, it was concluded that subjects trained in an activity similar to that used in the testing protocol needed only a verbal explanation of the machinery and test protocol in order to obtain reliable results.
The physical practice of the test protocol was found to be unnecessary for these types of subjects as no differences between muscular endurance tests were seen in the trained groups whose muscles were accustomed to muscular endurance activity.

Strength and power were found to be strongly related in all groups. It was concluded that since the same muscular physiological properties are needed for strength and power movements, subjects possessing a certain amount of one parameter have a predictable amount of the other. Since the relationships between isokinetic strength and power were found to be strong, the predictability of one parameter to the other was found to be quite accurate.

Only in the non-running female and total female groups were significant relationships seen between isokinetic strength and isokinetic muscular endurance. The significance in the total female group was due to the influence of the non-running group since significance was not achieved in the female running group. These relationships, like all the relationships observed between isokinetic strength and isokinetic muscular endurance in the female groups, were negative. The unrelated scores were hypothesized to be different due to the different muscular physiological properties necessary to perform strength and muscular endurance activities. Although the male groups did not have significant relationships between isokinetic strength and isokinetic muscular endurance, the relationships observed in these groups were in a positive direction.

It was reasoned that these relationships were positive as opposed to the females' relationships, which were negative, because the males had trained their muscles for these types of movements more extensively than had the females which brought the relationship closer.

Concerning the relationship between isokinetic power and isokinetic muscular endurance, once again the non-running female and total female groups showed a significant negative relationship. The significant relationship observed in the total female group was due to the significance found in the non-running female group as the running female group showed nonsignificance. Other relationships observed showed either no relationship, as in the running males and total males, or a weak, negative relationship.

Only one group, the total non-running, showed a positive relationship. That relationship, however, was very weak. The weak relationships seen between isokinetic power and isokinetic muscular endurance were explained again by the difference in the muscular physiological qualities necessary to perform power and muscular endurance activities.

Conclusions

Within the limitations of this study, the following conclusions were made.

With the subjects having no previous experience with isokinetic resistance and instrumentation, an orientation session which includes a verbal explanation and an actual run-through of the test protocol was found to be necessary and effective in producing more reliable test results on the isokinetic dynamometer.

Subjects having previous isokinetic resistance experience did not need an actual run-through of the test protocol in order to familiarize themselves with the machinery. However, it was found that a verbal explanation of the test protocol followed by warm-up contractions on the isokinetic dynamometer are necessary in obtaining reliable, accurate test results.

There was a strong positive relationship observed between isokinetic strength and isokinetic power. The reason for this strong relationship was seen as the similarity in the muscular qualities necessary to perform these two types of movement.

In males, the relationship between isokinetic strength and isokinetic muscular endurance was positive but low. In females, the relationship was found to be negative and higher.

The relationship between isokinetic power and isokinetic muscular endurance in males was very weak. In females this relationship was negative and stronger. These results indicate that the more strength or power a female may be capable of producing, the less muscular endurance she is likely to possess. Differences in the muscular properties necessary to these particular movements were seen as the reason for the finding of weak and negative relationships between isokinetic strength and isokinetic muscular endurance or isokinetic strength and isokinetic muscular endurance.

Recommendations

In light of the findings of this study relative to an orientation procedure prior to isokinetic testing, it is suggested that specific information concerning a subject's experience with isokinetic exercise be gathered prior to testing. This information will enable the researcher to determine if an orientation procedure is needed for a particular subject.

In addition to information concerning isokinetic exercise, specific information should also be gathered from each subject regarding previous muscular training experience. This knowledge could help the researchers better understand and explain the relationships observed among fitness parameters.

In the future, a study of this nature should make every effort to test subjects at equal intervals. For example, test all subjects two days after the orientation. Also, if two tests are being given and compared, an attempt should be made to test subjects at the same time of day each test day. In addition, each subject should be given the same amount of verbal encouragement during testing. These practices would better standardize test conditions and environment for each subject.

Another important aspect of testing to make a serious attempt to control is the amount of activity that a subject gets prior to testing. It is suggested that a subjcet not undertake any strenuous activity on the days of testing. Any low-level activity undertaken should be of the same nature and intensity on both test days.

An orientation session prior to isokinetic testing was found to be necessary in obtaining reliable results. It is recommended that further studies involving isokinetic testing test subjects three separate times and determine differences between the second and third tests. The findings would determine if two or three practice sessions are necessary before reliable test results using isokinetic instrumentation can be obtained.

It was observed in this study that although increases in test scores between tests many times were nonsignificant, they still existed. A third test would further define the reliability of scores after two tests.

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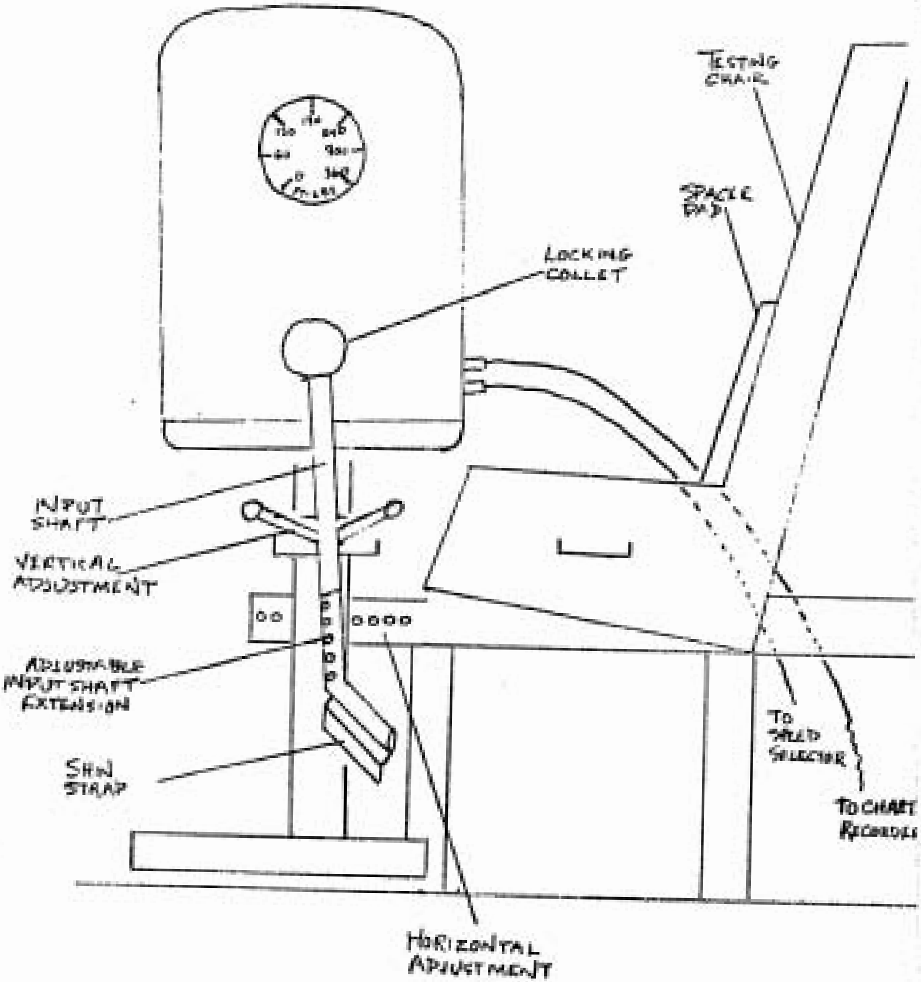
Appendix A

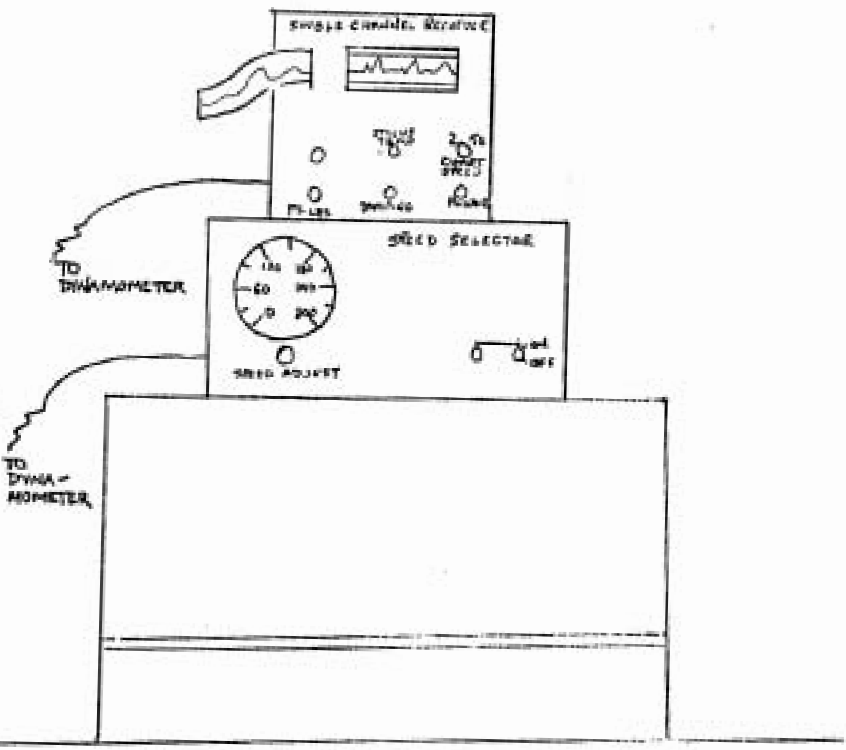
The Cybex II

Isokinetic Dynamometer



Appendix B

The Cybex II Single Channel Recorder and Speed Selector



Appendix C

Informed Consent

The testing procedure involves three different tests. The isokinetic strength test consists of three maximal contractions of the knee extensor muscles on the Cybex II isokinetic dynamometer at the slow contractile velocity of 60°/second. Isokinetic power will be tested by each subject performing three maximal knee extensions on the Cybex II at the following contractile velocities: 120°/sec., 150°/sec., 180°/sec., 210°/sec., 240°/sec., and 300°/sec.

Following a short rest of four to five minutes, the muscular endurance test will be given. The muscular endurance test consists of repeated maximal knee extensions for one minute at the fast contractile velocity of 180°/sec.

During and following the tests, local leg fatigue is expected. During all tests possible risks include muscle strain, muscle tear, and ligament damage to the knee. In addition, significant heart rate and blood pressure increases may be elicited from the tests.

To minimize the risk of injury from muscular exertion, each subject will undertake a series of warm-up contractions, at a slow, intermediate, and fast speeds prior to testing.

I fully understand the testing protocol which was explained to me and I assume the risks involved in the tests described to me. I am aware that I may withdraw from this study at any time.

Signed______________________________

Appendix D

Pre-test Subject Information

Name ______________________________ Age ______________

Height _______________ Weight ___________

Exercise Information

Activity ______________________ #times/week __________

How long or

#miles/session ________________Total #miles/week ______

Have you recently had an injury which restricted your activity?

What type of injury?___________________________________

When? _______________________ How treated?____________

____

Are you at 100% now? _______________________

Do you engage in any recreational activities beside the one you listed above?

What?______________________ How often? _______________

Appendix E

Cybex II Isokinetic Dynamometer

Calibration Procedure

Before each test, the Cybex II isokinetic dynamometer was calibrated for correct torque reading. The calibration procedure followed the guidelines set by Cybex, Lumex Inc., manufacturers of Cybex equipment. The procedure is outlined as follows:

1) Speed Selector ON, set at 5 RPM.

2) Chart Recorder ON, adjust Stylus to baseline. Turn to STAND-BY.

3) Range Scale to 180 foot-pounds.

4) Attach T-bar to dynamometer input shaft. Cross-piece of T-bar 31 inches from center of locking collet with 32.5 pounds of weights added to cross-piece. For 360 foot-pound scale, values are 30 inches and 70 pounds.

5) Raise T-bar to a position exactly perpendicular to the floor. If baseline shifts, adjust to zero as necessary after lowering T-bar.

6) With T-bar in raised position, turn Chart Recorder ON (2mm/sec.)

7) Release T-bar and let it fall to the floor.

8) Read torque deflection from Chart Recorder. Proper torque deflection is 5 major divisions. Adjust torque reading as necessary by turning the appropriate potentiometer screw found on the bottom case of the

bottom case of the Chart Recorder. To increase torque deflection, turn screw counterclockwise. To decrease, turn screw clockwise.

9) When both 180 and 360 foot-pound scales have been calibrated by showing torque readings of five major divisions four consecutive times, remove weights from T-bar, remove T-bar, and secure the appropriate attachment for testing to the input shaft.

Appendix F

Pre-test Checklist*

The Cybex II machinery was adjusted to each subject to fit his or her individual body size and shape. The following procedure checklist was followed prior to each test:

1) Chart Recorder to STAND-BY, 2mm/second.

2) Range Scale set appropriately (180 or 360 foot-pounds).

3) Speed Selector ON.

4) Subject positioned in chair with back flat against back of chair. Spacer pads as necessary.

5) Align Locking Collet with lateral mid-knee.

6) Fasten Thigh Strap just above knee.

7) Adjust length of Input Shaft so that the Ankle Strap can be attached just above ankle.

8) Have subject grip Side Handles or sides of chair.

9) Subject maintains a 90° angle at the knee.

10) Subject practice through a full range of motion at fast and slow speeds. Troubleshoot and make necessary adjustments.

11) Zero the Chart Recorder baseline.

12) Set Speed Selector at 60°/sec.

13) Chart Recorder switch to RECORD, begin testing protocol.

*Taken from Isolated joint testing and exercise. Cybex, Lumex Inc., Bay Shore, New York with modifications made by Tesch, J., tests for cross country skiers. University of Wisconsin, LaCrosse, June, 1980.

Appendix G

Power Calculation

Distance Traveled	Speed of Movement (Degrees/sec.)	Time to Complete Movement (sec.)	Ft.-Lbs. Recorded/time	Power (Ft.-Lbs/sec.)
90°	120	0.750	83/.750	110.67
90°	150	0.600	67/.600	111.67
90°	180	0.500	57/.500	114*
90°	210	0.429	45/.429	105
90°	240	0.375	39/.375	104
90°	270	0.333	30/.333	90.09
90°	300	0.300	22/.300	73.33

*Maximum Power Production

Appendix H

Muscular Endurance Calculation

Initial Strength (IS) (FT. - LBS.)	Final Strength (FS) (FT. - LBS.)	Strength Retention (SR) (Final/Initial)	% Decline in Strength (100 - SR)
70, 72, 68	30, 29, 28	29/70	100 - 41.43
Average = 70.00 (IS)	Average = 29.00 (FS)	=41.43% SR	= 58.57 % Decline

Appendix I

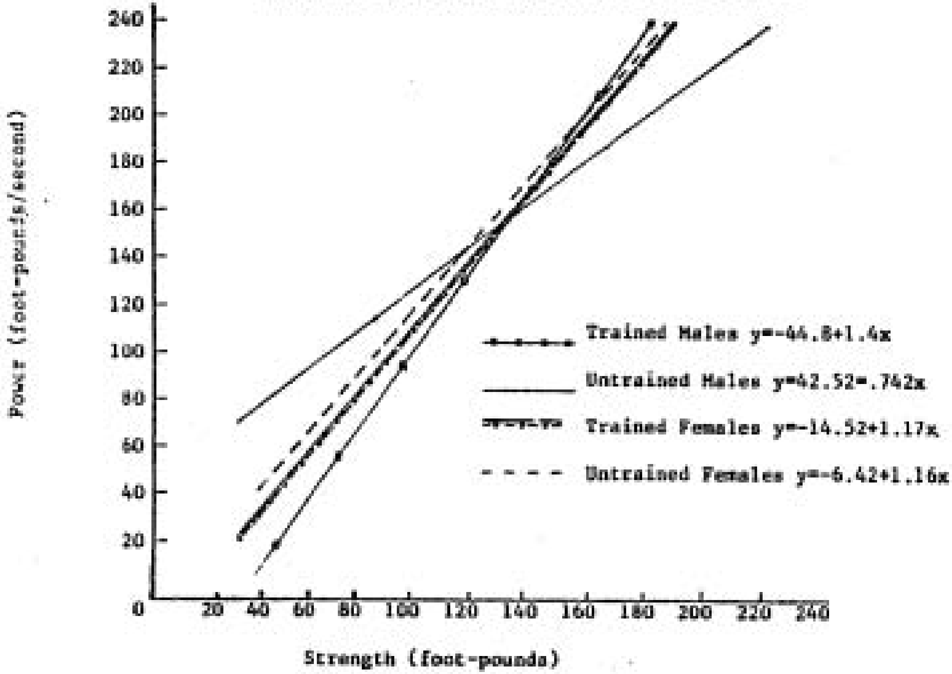
Resultant t Scores and Critical Values of t
Between the First and Second Test

GROUP	STRENGTH	POWER	MUSCULAR ENDURANCE
Trained Males	-14.024*	-4.317*	0.972
Critical $Value_T$	2.101	2.101	2.101
Untrained Males	0.312	-0.054	-0.419
Critical $Value_T$	2.101	2.101	2.101
Trained Females	-3.104**	-3.138**	1.259
Critical $Value_T$	2.160	2.160	2.160
Untrained Females	-3.584**	-4.598*	3.066**
Critical $Value_T$	2.056	2.060	2.060

*Significant at $P<.001$ level
**Significant at $P<.01$ level

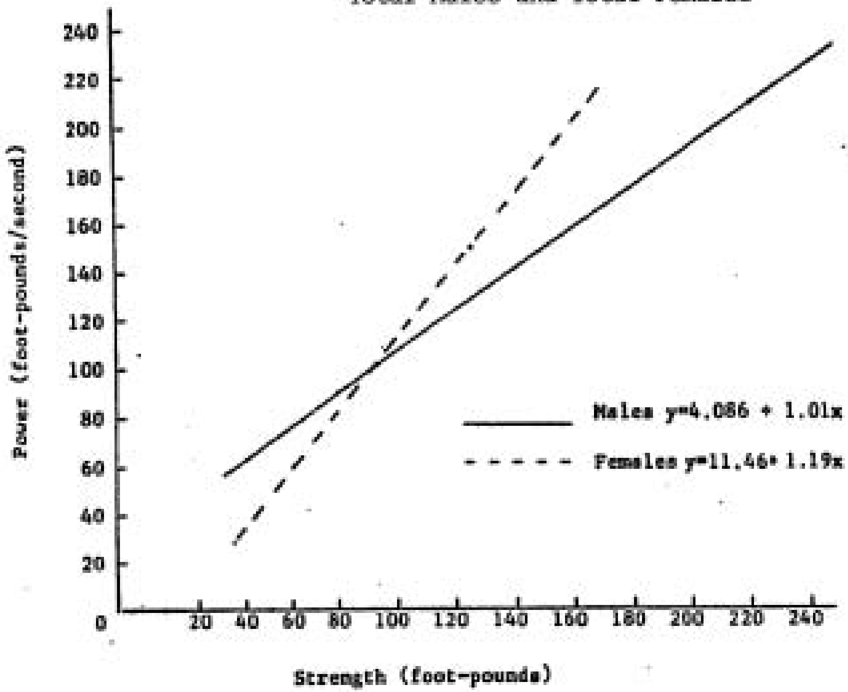
Appendix J

Linear Regression Lines and Equations of Isokinetic Strength Predicting Isokinetic Power in Trained and Untrained Males and Females



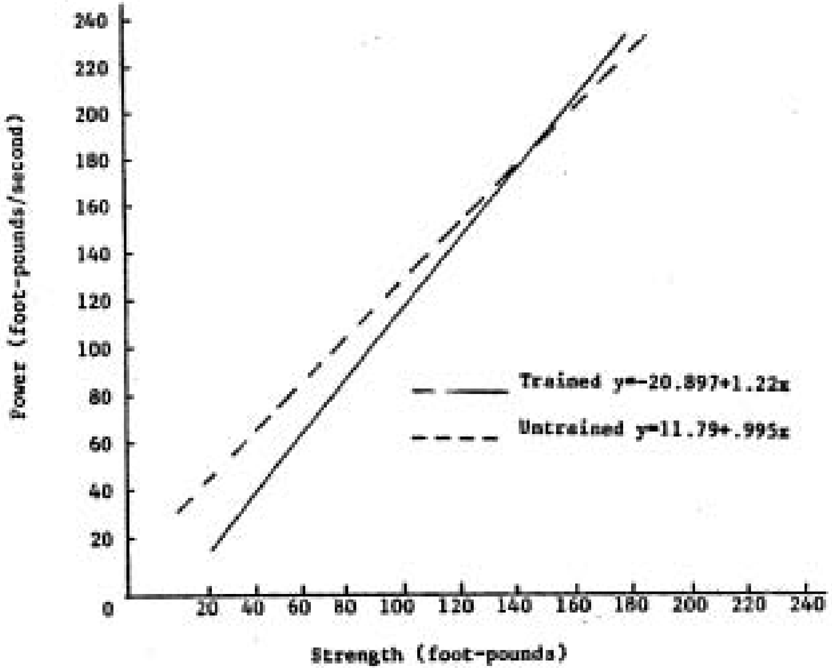
Appendix K

Linear Regression Lines and Equations of Isokinetic Strength Predicting Isokinetic Power in Total Males and Total Females



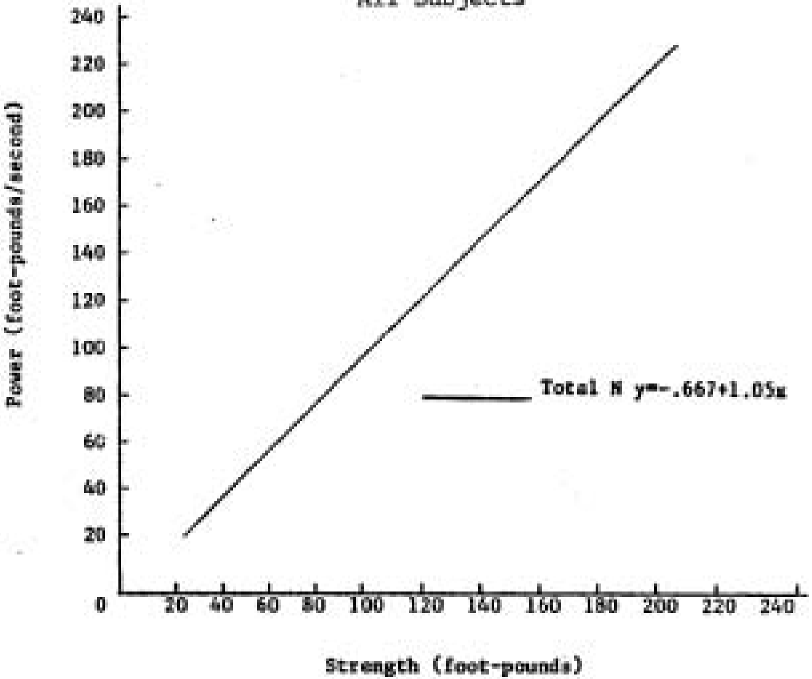
Appendix L

Linear Regression Lines and Equations of Isokinetic Strength Predicting Isokinetic Power in Trained and Untrained Subjects



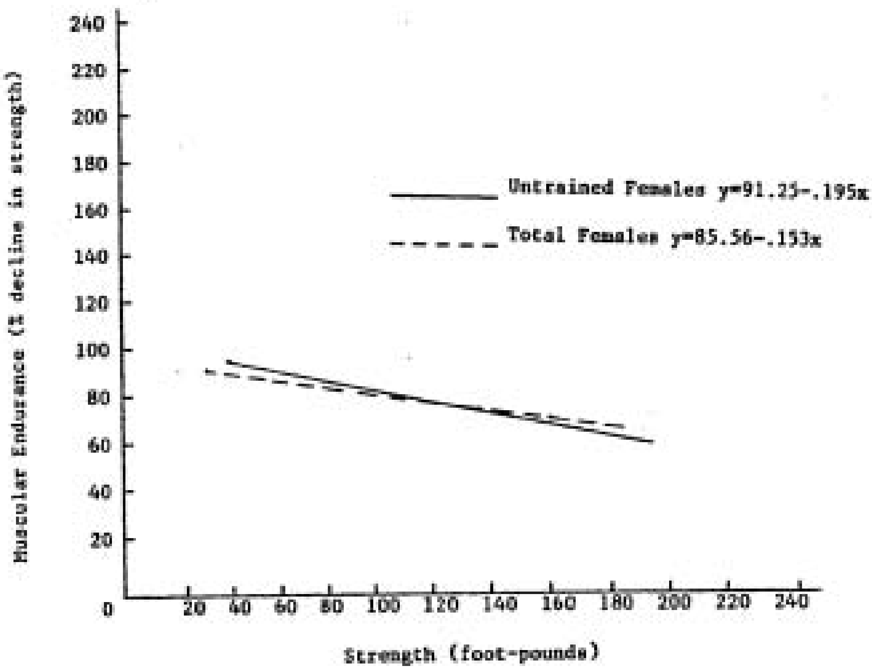
Appendix M

Linear Regression Line and Equation of Isokinetic Strength Predicting Isokinetic Power in All Subjects



Appendix N

Linear Regression Lines and Equations of
Isokinetic Strength Predicting Isokinetic Muscular Endurance in
Untrained and Total Females



Appendix O

Linear Regression Lines and Equations of Isokinetic Power Predicting Isokinetic Muscular Endurance in Untrained and Total Females