AN ABSTRACT OF THE THESIS OF

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in Health, Physical Education, Recreation & Athletics presented in May

1986. Title: The Effects of Bilateral Versus Unilateral Strength

Training on Leg Power

Abstract approved: [signature]

The purpose of this study was to compare the effects of a bilateral vs. a unilateral leg strengthening program on leg power. Forty-two subjects were randomly assigned into treatment groups. The four treatment groups were C_1 (pretested bilateral), C_2 (non-pretested bilateral), E_1 (pretested unilateral) and E_2 (non-pretested unilateral). C_1 and E_1 were pretested on tests of power (Margaria-Kalamen power test), strength (hipsled 1 RM), and speed (40 yard dash). All four groups participated in a six-week treatment phase in which C_1 and C_2 utilized bilateral leg strengthening exercises and groups E_1 and E_2 used unilateral leg strengthening exercises.

A factoral two way ANOVA and Fisher's test of least significant difference illustrated that significant differences occured between

group means on the power and strength tests. On the power test, groups C_1, C_2, and E_2 were found to be significantly higher than E_1. (These results lead to the rejection of the hypothesis that all of the treatment group means would be equal.) The strength test showed that groups C_1 and E_2 were equally higher than groups C_2 and E_1. No substantive association could be made between strength and power gains per group.

Based on the results of this study, there are significant differences between bilateral and unilateral conditioning groups regarding power performance. Upon closer examination, evidence supports the fact that bilateral strength training is more conducive to power enhancement.

THE EFFECTS OF BILATERAL VERSUS UNILATERAL STRENGTH TRAINING ON LEG POWER

A Thesis

Presented to

The Division of Health, Physical Education,

Recreation and Athletics

EMPORIA STATE UNIVERSITY

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Paul W. Miller

May, 1986

Approved for the Major Department

Approved for the Graduate Council

453001 DP AUG 26 '86

Acknowledgements

Contributing invaluable assistance to this study were:

Dr. Patricia McSwegin	For setting high standards and offering expert guidance in conducting this study; for serving as chairperson of the writer's committee.
Dr. Loren Tompkins	For providing crucial statistical and design background; for his availability; for serving on the writer's committee; for offering his unique style of encouragement.
Mr. John Baxter	For offering crucial research materials; for providing an additional common sense approach; for always offering aid and support.
Head Football Coach Larry Kramer, Randy Mathews, and the entire E.S.U. staff and players	For allowing this study to utilize the E.S.U. football players as subjects; for total cooperation and assistance in conducting the tests and treatment of the subjects.
Carol, Owen and Ross Miller	For providing a sense of purpose and reality to a world often gone mad.

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Chapter 1

Introduction

As a group, athletes and coaches are in constant pursuit of performance improvement. Successful performance usually entails raising athletic skill levels above those of an opponent. Athletic skill enhancement involves correct channelling of diverse human movements. Development of superior movement patterns hinges upon the development of the skeletal, nervous, and muscular systems of the body. One very popular method of increasing the proficiency of these systems is the use of a supplemental strength training program.

The purpose of most supplemental strength training programs is to increase muscular strength, power, speed, and endurance. These aspects of fitness are important to successful performance by almost all athletes (Wilmore, 1976). Although muscular strength, power, speed and endurance are all interrelated, each has its own definitions.

Muscular Strength: The force or tension a muscle, or muscle group can exert against a resistance in one maximal effort (Fox & Mathews, 1981, p. 139).

Power: The amount of work performed per unit of time (Fox & Mathews, 1981, p. 57).

Muscular Endurance: The ability or capacity of a muscle group to perform repeated contractions against a load or to sustain a contraction for an extended period of time (Fox & Mathews, 1981, p. 145).

Speed: As it relates to muscular power, speed is the rapidity with which one contracts a muscle or group of muscles (Stone &

Kroll, 1978, p. 39). Speed in locomotion (running) is the product of stride length times stride frequency.

Since strength is the ability of a muscle group to apply or to resist force, a person who can leg press 800 lbs. has twice the strength of a person who can press 400 lbs. Power is simply the result of strength times speed. If two subjects can lift 200 lbs. above their heads, but subject A can lift it twice as fast as subject B, then subject A has twice the power of subject B. While strength is an important component of performance, power is probably even more important for most sport activities (Wilmore, 1976). Muscular endurance is necessary for improving sport performance because most skill execution requires many repetitions of movements. While strength appears to be an isolated component, both muscular endurance and power are dependent on the individual's level of strength (Wilmore, 1976).

Muscular endurance is usually associated with isolated areas of the body, such as the arms in rowing or the legs in bicycling. However, most sporting events require isolated muscular endurance in more than one area of the body. Weight training and aerobic training are utilized in the development of muscular endurance. Strength is an important part of muscular endurance. An example of this would be if two athletes were applying the same amount of force against a resistance, the stronger of the two should fatigue less quickly because the percent of total strength used to apply identical resistance is less.

Power is often referred to as explosive strength. Examples of power athletes are shot putters, sprinters, power weightlifters, and football players. Strength building has the greatest potential to contribute toward better performance in those events requiring explosive strength. The great increase in dynamic strength that accrues from weight training can be utilized directly when applying force rapidly (Stone & Kroll, 1978). Research has indicated that the speed component in power output is based on the heredity of the individual and that this does not change following endurance, sprint, or weight resistance training (Fox, 1979). Therefore, power enhancement must hinge upon strength development.

If one were to rate sports in which power were most essential, football would be high on the list (Fox & Mathews, 1974). The nature of the sport requires explosive strength for successful performance. The average play lasts approximately 5-7 seconds with the players "resting" anywhere from 30-60 seconds between plays. As a result, during the course of an entire 60 minute college football game, an average offensive or defensive player will actually be involved a total of only 6-8 minutes of performance movement time. The relatively great amount of time spent between plays, in non-performance movement, allows the players to replenish the stored energy expended during the quick, explosive actions.

Speed, strength, acceleration, and agility are the basic elements of football and, therefore, are requirements of the athletes who play the game (Stone & Kroll, 1978). Leg power is directly responsible for speed, acceleration of the body, and agility, and is a major component of overall body strength. Therefore, to maximize speed, acceleration, agility, and to a large extent overall strength, leg power development is crucial.

One of the most popular ways to increase leg strength (thus, leg power) is through supplemental strength training. Most strength training programs utilize isotonic weight training (moving the muscle or muscle group through a full range of motion against resistance). Isotonic programs are based on a number of principles designed to properly overload the specific muscle groups in a progressive manner throughout the training period. The overload principle is based on the premise that strength is developed most effectively when a muscle or muscle group is exercised against maximal or near maximal resistance.

The principle of specificity requires that one not only exercise the same muscle groups that will be utilized during the skill performance, but also carry out the exercises in corresponding ranges and angles of movement. The progressive resistance principle deals with the amount of resistance used during a program. During the course of a strength training program, the exercised muscle group will get stronger. As strength is gained it is important to increase the resistance used during the exercise.

In a good isotonic weight program it is critical that larger muscle groups get exercised before smaller muscle groups. The reason for this is that smaller muscle groups fatigue sooner. In order for the larger muscle groups to get properly taxed, it is necessary that the smaller muscle groups do not fatigue first. Another consideration in the program is that no two large muscle groups get exercised in succession. This ensures adequate recovery time between lifts.

Isotonic weight training programs are based on the "sets and repetitions" principle, first publicized by DeLorme and Watkins (1948). A basic concept in their principle is the repetition maximum (RM), which is the maximum amount of weight a muscle or muscle group can lift a certain number of times (repetitions) without failing due to fatigue.

Among today's weight training coaches, it is generally agreed that an isotonic weight training program of three days per week will result in significant gains in strength without risking the possibility of chronic fatigue. Adequate recovery not only refers to recovery from day-to-day, but also from exercise-to-exercise. Sufficient time between sets should be allowed for recovery of energy.

Specificity in training refers to matching the conditioning or strength demands of the sport to the training techniques (Stone & Kroll, 1978). In strength training specific to a sport, it is very important to condition the same muscle groups that are directly involved in performance of a particular sports skill. Equally important is conditioning of the specific muscle groups using movement corresponding to patterns which coincide with the particular movement patterns of the skill.

Since leg power is such a critical aspect of football, much attention is given to leg strength development in various supplemental weight programs. Popular exercises that are designed to increase leg strength include the squat, leg extensions, hamstring curl, and heel raises. Most machines, especially the relatively inexpensive ones, designed to facilitate leg extension, hamstring curl, and heel raising exercises allow for, and encourage the use of both legs working simultaneously (bilaterally) in the movement. The squat is always done with bilateral leg involvement.

In compliance with sport "specificity in training" concepts, bilateral leg training techniques should be consistent with action in particular football skills, however, there are few actions in football that require bilateral movement of the legs. The legs certainly do work together as a unit, but within this unit they must work independently (unilaterally), with various power outputs. Football players are coached to have an evenly distributed center of gravity during impact and quite often this is achieved in a practice situation. However, in a game situation, where the skill and motivation level of an opponent is higher, the athlete must make split-second adjustments to an opponent's changing center of gravity in order to make a successful play. Usually, successful skill execution is not made with "perfect form," which is a balanced center of gravity with bilateral exertion of leg power. Quite often, due to the quick adjustments, the skill must be performed by exerting a greater percent of leg power output unilaterally.

Statement of the Problem

The problem with bilateral weight training regarding leg strength gains is twofold. There is the problem of specificity in training, and the problem of asymmetrical strength development. As stated earlier, popular bilateral leg strengthening exercises, such as the squat, leg extensions, hamstring curls, and heel raises, do not stimulate actual leg power output which occurs during the course of a football game.

Asymmetrical leg strength development is interrelated with the specificity problem just cited. If the right quadricep group is stronger than the left, the right group will have a tendency to do a greater percentage of work to complete a set of repetitions. Thus, the right quadricep group gains a greater percentage of strength throughout a program. Asymmetrical strength development presents crucial implications in regard to specific player alignments and skill performance against opponents on the playing field.

Purpose

It was the purpose of this study to determine the effects of bilateral vs. unilateral leg strengthening exercises, on leg power. This was done by comparing the results of subjects using a bilateral leg strengthening program to subjects using a unilateral leg strengthening program, as measured by the Margaria-Kalamen leg power test. The training program lasted six weeks. The subjects were divided into two unilateral groups (E_1 and E_2), and two bilateral groups (C_1 and C_2). E_1 and C_1 were pretested, all four groups were posttested in the leg power test, a leg strength test (hip sled max.), and a speed test (40-yard dash). It was a secondary intent of this study to use the leg strength test and speed test results to support the theory that power is gained largely through strength development.

Significance

One common concern among administrators of all strength training programs is efficiency. The program must be designed not only to increase strength in the specific muscle groups used in particular skill performance, but also must simulate muscle movement coinciding with the playing action. Working muscle groups or actions that will not yield direct improvement in playing ability is not efficient.

There is a relatively small amount of literature available on the effects of bilateral versus unilateral leg power development, particularly as it relates to football. This study will give strength program administrators, coaches, and athletes added insight into the most efficient way to design their programs to improve athletic performance, particularly in football.

Chapter 2

The primary purpose of this study was to determine if there were any significant differences between unilateral leg strength training programs and bilateral leg strength training programs, regarding leg power gains as measured by the Margaria-Kalamen power test. This chapter points out the need for supplemental strength training programs for performance improvement. Then a review of current concepts of literature regarding muscular strength, speed, power and endurance enhancement is presented. That review focuses on the power factor, spcifically leg power, and its importance to general and football athletic skill development. Isotonic weight training principles are described and, most importantly, related literature regarding the unilateral versus bilateral concept is explained. This chapter concludes with a summation of the materials set forth.

Related Literature

For sport preparation, the coach or athlete actually has two major objectives: development of skills and strategies used in game situations and enhancement of physical conditioning to the level needed for top performance (Stone & Kroll, 1978). The actual practice of a sprot is obviously the best way to perfect the skills needed to succeed against an opponent. Some sports, however, do not make sufficient demands on all of the physiological systems needed to achieve optimum performance. That is when a supplemental physical conditioning program is needed to further condition the athlete's physiological systems.

An integral part of almost all physical conditioning programs is strength training. Strength training programs are utilized to develop any one or more of the following components: muscular strength, speed, power, and endurance. It is obvious that strength training is important for sports such as football, weightlifting, shotputting, and wrestling. However, the value of strength training programs to improve performance in basketball, golf, or long distance running, is not as obvious, but Wilmore (1976) suggests that strength, power, speed, and muscular endurance are important to successful performance by almost all athletes. Consequently, strength, power, speed, and muscular endurance training is an integral part of the training program for almost all sports and physical activities.

Clarke (1974) summarized the research pertaining to muscular strength, power, speed, and endurance in reference to performance improvement. It should be noted that although this summarization appears to be outdated, it has served as a legitimate basis by many contemporary texts and research studies (Fox, 1979). Clarke found that "with regard to specific sports, muscular training appears to be a highly desirable supplement to the general training program for almost any athlete" (p. 3). In three studies of baseball, muscular training as a supplement to regular practice yielded significant improvements in throwing speed and in sprinting speed. In a single study of ftball, underhand throwing ability for distance was improved as well muscular endurance to maintain a maximum velocity over the course 80 underhand throws. Several studies in swimming showed the sitive influence of strength training, especially in sprints. In otball, the influence of weight training on speed and force of the fensive football charge was investigated in a single study. The ight trained groups improved significantly in both speed and force the offensive charge, while the control group did not improve on ther test.

While strength training has been proven to be effective in the provement of performance, another important result is injury evention. This concept is extremely significant to athletes who rticipate in sports involving body contact and collision, such football, hockey, and lacrosse. In early supplemental strength aining programs for football, the objective was primarily for jury prevention and not for skill enhancement (Ecker & Jones, 62). Football coaches in the mid to late 1950's desired "extra dding" for their players to help absorb blows. They advocated rength training as a means of providing such padding. More recently, do (1985) points out that a properly devised weight training program n develop muscular tendon and ligament strength and structural body lance, all of which aid in injury prevention.

The term "strength" is widely used (and misused) when discussing pplemental training programs to improve performance. Fox and thews (1981) refer to strength as "the force or tension a muscle or, more correctly, a muscle group can exert against a resistance in one maximal effort. Morehouse and Miller (1976) term strength as the maximal tension that an isolated muscle can exert. Wilmore (1976) says strength is the "ability to apply or to resist force. These definitions are moderately generic in that the contraction type (dynamic or static) and duration are not identified. Atha (1981) prefers a more rigorous definition, the ability to exert maximal torque in a single, isometric contraction of unlimited duration. When velocity of the contraction is considered, the term power is applied.

Power is referred to as the amount of work performed per unit of time (Fox & Mathews, 1981). This is also referred to as power capacity (Margaria, Aghemo, & Rovelli, 1966). Wilmore (1976, p. 89). defines power as "simply the product of strength and time." Assuming that strength is the essential element underlying "work", Wilmore's definition relates closely with Fox and Mathew's.

Speed, as it relates to muscular power, is the rapidity with which one contracts a muscle or group of muscles (Stone & Kroll, 1978). Research over the past several years has shown that performance in various physical activities is, to a great extent, dependent upon an individual's muscle fiber composition (Thorstensson, Larsson, Tesch, & Karlsson, 1977). There is evidence that individuals possessing a high proportion of fast twitch muscle fibers (see Appendix B for detailed discussion) are better suided for activities requiring maximal force production at high speeds (Thorstensson, Grimby, & Karlsson, 1976). The percentage of fast and slow twitch muscle fibers does not change as a result of training, but there is evidence that the fiber-type most often and intensely overloaded will experience an increase in percent volume. Furthermore, studies have shown that the fast/slow twitch fiber ratio is determined soley by heredity (Fox, 1979).

Strength is not only critical in power output, it is also an important component in endurance. Muscular endurance is the ability or capacity of a muscle group to perform repeated contractions against a load or to sustain a contraction for an extended period of time (Fox & Mathews, 1981). Because most athletic performance requires repetition of movements, improvement of muscular endurance is critical to performance enhancement. Strength is a significant factor in muscular endurance. If subject A is stronger than subject B, subject A will be able to sustain an equal number of static or dynamic contractions as subject B, using a smaller percent of total strength. Hence, subject A is expending energy at a lower rate than subject B to do the same work, therefore, subject A's energy stores should last longer.

A basic understanding of the various types of muscle contraction is necessary in comprehending how the body adapts to the strength training. Most texts classify muscular contractions into four categories: isotonic, isometric, eccentric, and isokinetic.

Isotonic (Dynamic, or Concentric) Contraction. This is a type of contraction where the muscle shortens as tension is introduced. This contraction is most commonly required in actual sport performance and is the type of muscular contraction stimulated in free weight strength training programs. The muscle is taken through a full range of motion in isotonic exercises. The main disadvantage to isotonic contractions with regard to strength development is that the effort to exert force upon a resistance, throughout the full range of motion, is not uniform. As a weight is lifted, the mechanical advantage, via joint angle change, becomes greater, thus, the muscle does not have to work as hard at certain points in an exercise. The result is that maximal exertion only occurs at specific points of the movement instead of contracting maximally throughout the entire range, therefore, strength development is less at those angles where maximum exertion is not exhibited.

Isometric (Static) Contractions. In this type of contraction, the muscle develops tension, but does not change in length. "Iso" means same, and "metric" means length. An example of this type of training activity would be to hold a bar horizontally for a period of time or push against a static object. The primary disadvantage to isometric strength development is that the muscle is not taken through a range of motion. Several studies have indicated that isometric strength gains are specific to the joint angle trained. An example of this is performing isometric training at a 90^{o} angle in the biceps curl. Such training will lead to substantial strength gains at that angle but will yield relatively small amounts of strength gain at the 45^{o} and 135^{o} angles (Wilmore, 1976).

Eccentric Contractions. During this type of contraction the muscle lengthens as it develops tension. This is just the opposite of concentric contractions. Examples of this type of activity would be walking or running downhill or lowering oneself from a chinning bar. "Negative resistance" exercises in weight training would also fall into this category. Because a muscle can maximally produce nearly 40 percent more tension eccentrically than concentrically, ways of developing superior strength through eccentric exercises have been the subject of many studies. However, results of various studies show that training with maximal eccentric contractions produced no greater increases in strength than did training with maximal concentric contractions (Fox, 1979). Eccentric exercises do seem to have a role in optimal strength gains via supplemental training programs, according to work by Komi and Buskirk (1972), who demonstrated that eccentric training causes a significant increase in concentric, eccentric, and also isometric tension. Later, Pletnev (1975) found that the combination of isometric, concentric, and eccentric training was more effective for strength development than the concentric training alone. Hakkinen and Komi (1981) also supported this finding through their research.

Another characteristic that is associated with eccentric contractions is muscle soreness. Talag (1973) studied the effect of concentric, isometric, and eccentric contractions on muscle soreness. Findings illustrated a significant increase in muscle soreness resulting from eccentric contractions when compared to concentric and isometric contractions. The study also found that muscular strength decreased appreciably following eccentric contractions and remained depressed throughout the duration of the soreness period. This was not found to occur in concentric and isometric contractions.

Isokinetic Contraction. This type of training is relatively new. "Iso" has been defined to mean same, and "kinetic" means motion. In this contraction the muscle goes through the full range of motion as tension develops. The difference between isokinetic and isotonic contractions is that in isokinetic contractions the tension remains constant, even as mechanical advantage is gained due to joint angle alteration. Isokinetic exercise machines are designed to gradually increase resistance as the muscle group gains mechanical advantage throughout the range of movement. The need for constant contraction exertion through the full range of motion is inherent in the exercise.

Many researchers regard isokinetic strength training as the best suited for improving athletic performance (Fox, 1979). One of the most comprehensive studies was done by Pipes and Wilmore (1975). In their study, they looked for differences in changes in strength, body composition, anthropometric measurements, and selected motor performance tasks between groups trained isotonically and isokinetically. The results demonstrated a clear superiority of the isokinetic training procedures over isotonic procedures relative to strength, gain, anthropometric measures and motor performance tasks. One experimental group (the isokinetic high-speed group) demonstrated the greatest gains overall.

From a practical standpoint, isokinetic training has two drawbacks: it requires relatively expensive exercise machines and a peer-related motivational factor. Also, most isokinetic strengthening and testing machines are priced beyond the limits of the majority of athletic budgets.

Regarding motivation, many strength programs utilize a poundage club system. An example would be that to get into the "warrior club" and get a gold warrior shirt, an athlete must bench press 300 lbs. This motivational technique has been proven effective, especially at younger levels of athletics. Many athletes are motivated by how much they can isotonically "max" in a certain exercise.

The majority of supplemental strength programs utilize isotonic contractions (although, as cited earlier, isokinetic is probably best suited for strength-speed gains). There is a popular belief among coaches and strength program coordinators that "free weights" yield the best power results. Isotonic strength programs are based on a number of principles designed to properly overload the specific muscle groups in a progressive manner throughout the training period.

<u>The Progressive Overload Principle</u>. Overloading means that in order for muscular adaptations (in this case strength development) to occur, the specific muscle or muscle group must work harder than normal. The amount of overload and intensity with which a muscle or muscle group is trained will determine the degree of muscular adaptation.

Provided the load is constant from day to day, the body will first adapt to the load. When adaptation to the load is complete, the body will no longer improve as a result of the training (Morehouse & Miller, 1976). Additional or progressive overloading must take place in order to attain greater improvement. In a weight program, additional overload can be in a number of forms. The resistance can be increased, the repetitions can become quicker, or the duration of each exercise can become greater, depending on what type of intensity and duration of muscular contractions an individual is training for.

Specificity in Training. Physical conditioning for any sport should match the physiological demands of the activity. For example, football requires a series of "all out" bursts of energy followed by a short recovery period (Stone & Kroll, 1978). A supplemental strength program for football should, therefore, involve exercises of high intensity for relatively short duration. Edgerton (1976) believes that maximal efforts should be no longer than six seconds if overload of the FG fibers is the objective. After six seconds the effort is considered submaximal due to diminishing FG fiber involvement.

Sport specific strength training programs must be concerned with the various muscle groups that are directly related to skill success. In a sport such as football, optimum strength development in all of the large muscle groups (chest, upper arms, upper and lower back, abdominals, hip, and upper legs) is critical. In a strength training workout, these large muscle groups should be overloaded to fatigue first, followed by exercises concentrating on the supplemental muscle groups including the lower arms, lower legs, and neck (Stone & Kroll, 1978).

Fox (1979) states that strength development is specific not only to the muscle groups and intensity levels involved, but also to the movement patterns exhibited in the sports skill. This would indicate motor skill specificity. The central nervous system adapts to physical activity of the type that makes demands on it (Morehouse & Miller, 1976). Repeated performance of a movement pattern induces conditioned reflexes which enable the physical activity to be performed more precisely and, if overloaded, allows the movement pattern to take place with more power.

Sets and Repetitions. Most isotonic strength programs are presently based on the sets and repetitions principle for exercising various muscles or muscle groups. The principle was first published by DeLorme and Watkins (1948). They designed a progressive resistance program for rehabilitative purposes of injured patients. They prescribed that the patient lift a weight ten times during each set. After a rest period of 2-3 minutes, the set is repeated. Each exercise session consists of three sets of ten lifts (repetitions) each. Since then, strength programs have evolved into varying numbers of sets and repetitions (reps.), depending on the objective of the program. The basic concept of DeLorme and Watkins, however, is still utilized today.

The basic principles of an effective isotonic strength program just discussed bring about successive physiological adaptations both neurologically and muscularly (see Appendix B for basic knowledge and term definitions). Evidence supports the fact that strength training influences "neural factors" affecting force output. These neural adaptations are thought to be responsible for significant strength gains early in a strength training program, prior to hypertropy (Hakkinen & Komi, 1983). Houston, Froese, Valariote, Green, and

Ranney (1983) conducted a study in which they trained one leg of subjects for strength and did not train their other leg. Significant strength gains were made in the untrained legs of the subjects with no accompanying hypertrophy. This led them to believe that there was a strong argument for neural adaptations taking place prior to hypertrophy. It is thought that these neural adaptations are the result of an individual's ability to fully activate a greater percentage of motor units (Lesmes, Costill, Coyle, & Fink, 1978). Strength training programs that consistently tax muscles to the point of failure may increase the ability to fully recruit all motor units (Howard, Ritchie, Gater, Cater, & Enoka, 1985).

Inherent in strength training programs is the intensity and duration with which a muscle contracts. Variations in force output results from two mechanisms at the motor unit level: (1) rate coding, and (2) recruitment (Howard, Ritchie, Gater, Gater, & Enoka, 1985). Rate coding is determined by the frequency with which action potentials occur (Appendix B). Motor unit recruitment includes the total percentage of fibers recruited, as well as the order with which they are recruited.

Motor units are classified according to three physiological properties: speed of contraction, magnitude of force exerted, and resistance to fatigue. Based on this premise, motor units have been categorized into three groups: SO (slow-twitch oxidative), FOG (fast-twitch oxidative glycolytic), and FG (fast-twitch glycolytic) units. Type SO units are slow-contracting, exert the least force, and fatigue resistant. FOG units are fast-contracting, exert immediate force, and are fatigue resistant. Type FG units are fast contracting, capable of exerting high force, and are quick to fatigue (Edgerton, 1976). The terms "oxidative" and "glycolytic" used in the description of SO, FOG, and FG motor units refer to the source of energy in which ensuing contractions take place. For a detailed discussion of energy production regarding muscle contractions, see Appendix A (metabolic considerations). These fiber-type characteristics are critical factors in determining the intensity and duration of sport-specific strength training exercises.

Strength development is directly related to the tension exhibited by the muscle fibers. Research supports the fact that when a muscle contraction takes place, the specific tension exerted is the same for SO, FOG, and FG fibers. A study by Howard, et al. (1985), showed that the three fiber types exerted the same amount of force per unit of cross-sectional area. However, research has also supported the fact that there are differences in specific tension among the fiber types (McDonagh and Davies, 1984).

Regarding strength increases, if the specific tension among fiber types is constant, strength gains must result from increases in cross-sectional area. Tesch and Larsson (1982) reported that there seems to be a limit on size potential of an indiviaul muscle fiber's cross-sectional area. This suggests that muscle hypertrophy might be dependent on an individual's fiber-type. McDonagh and Davies (1984) found that force output corresponds directly with muscle cross-sectional area. Hence, muscle hypertrophy seems to be important in strength development (Clarke, 1973). It is established that strength training results in hypertrophy (McDonagh & Davies, 1984). Fox and Mathews (1981, p. 146) state that hypertrophy of individual muscle fibers is caused by one or more of the following changes.

1. Increased number and size of myofibrils in each muscle fiber.
2. Increased total amount of contractile protein, particularly in the myosin filament.
3. Increased capacity density in each fiber.
4. Increased amounts and strength of connective, tendinous, and ligamentous tissues.
5. Increased number of fibers, resulting from longitudinal fiber splitting.

Research indicates that the various motor units adapt in different ways to resistance training. A sound strength training program implemented by an individual who is not used to training will cause all three types of motor units to adapt in a positive way toward strength development. However, the degree of adaptation that occurs for specific unit types depends on the type of strength training program incorporated. There is evidence that a program utilizing weight exercises done with a relatively low resistance for a longer duration will cause more adaptation to occur in the FOG and SO units (Edgerton, 1976). Research also indicates that maximal, or near maximal, resistance training for shorter durations will cause greater adaptations to occur in the FOG and FG units. FOG unit adaptation is inherent in both endurance-type and power-type resistance programs.

Motor units are categorized on the basis of enzyme activity congruent to the intensity and duration of exercise (Appendix B). FOG motor units present an inconvenient problem for many researchers. FOG motor units are relatively few in number (when compared to other mammals), especially in non-endurance trained individuals. All fast-twitch fibers seem to be more susceptible to fatigue when compared to slow-twitch fibers. The oxidative capacity of most fast-twitch fibers seems to very low. However, in endurance trained individuals, such as cross-country runners, one can see little difference in the NADH-D (nicotinamide adenine dinucleotide diaphorase - amount of this enzyme activity generally represents the oxidative capacity) activity between presumably slow- and fast-twitch fibers (Edgerton, 1976). To categorize fibers on the generic basis of slow or fast (Type I or Type II) is convenient, but does not take into account fundamental properties related to endurance (1976). FOG fibers seem to be important in both endurance-type and explosive-type (power) contractions.

The present study was concerned with power, or anaerobic strength development. As stated earlier, power is the amount of work performed per unit of time (Fox & Mathews, 1981). More simply, power can be thought of as the product of strength times speed (Wilmore, 1976).

According to Henneman's (1957) orderly recruitment theory, in a power or explosive movement, the SO fibers are recruited first. As the intensity of exertion increases, the FOG and FG fibers become more important. The relative importance of FOG and FG fibers becomes greater as the speed and force of the contraction increases (Edgerton, 1976).

The question of why some individuals seem to be better suited for power-type activities and why some are more suited for endurance-type activities has been the focus of many studies. It is generally believed that percentages of SO, FOG, and FG fibers in individuals vary from person-to-person and seem to be influenced almost totally by hereditary (Fox, 1979). It is also generally agreed that specific strength training regimens do not cause one type of fiber to convert into another type, although this has been indicated to be untrue in certain high-intensity endurance activities (Pette, 1984).

It has been suggested that persons possessing a high proportion of fast contracting muscle fibers are better suited for activities requiring maximal force production at high velocities (Thorstensson et al. 1976; Bosco & Komi, 1979); Hakkinen & Komi, 1983). Coyle, Costill, and Lesmes (1979) investigated muscle fiber composition and leg extension power. Their purpose was to relate muscle fiber composition to the isokinetic measure of peak torque production through a range of leg extension velocities. Percentages of fast- and slow-twitch fibers were obtained from 21 males through biopsies of their vastus lateralis. They found that subjects with predominately fast-twitch fibers were able to generate 11, 16, 23, and 47 percent greater relative peak torque than could predominately slow-twitch subjects at speeds of 115, 200, 287, and 400 degrees/second respectively. A study done by Thorstensson et al. (1976) on the force-velocity relations and fiber composition in the human knee extensor muscles found that a correlation existed between peak torque produced at the highest speed of muscle shortening and percent, as well as relative, area of fast-twitch fibers in the contracting muscle. In addition, they found that muscles with a high percentage of fast-twitch fibers had the highest maximal contraction speeds.

A study done by Coyle et al. (1981) investigated the specificity of power improvements through slow and fast isokinetic training. They divided their subjects into four experimental groups. All four groups participated in a six week, three times per week leg strengthening program using the isokinetic knee extension exercise. The first group's extensions were done at a velocity of 60 degrees/sec. (slow). The second group's extensions were at a 300 degree/sec. velocity (fast). The third group used both fast and slow extensions (mixed). The fourth group was considered the control group and the extensions were extremely submaximal. The fast group demonstrated a significant enlargement of fast-twitch fibers. They suggested that these data might indicate that fast-twitch fiber hypertrophy was the plausible mechanism for the nonspecific improvement of the fast group.

Tesch and Larsson (1982) compared fiber composition of the body builders with competitive power lifters with respect to distribution of fast-twitch and slow-twitch fiber types and different indices of fiber area. In comparison to the body builders, the power lifters demonstrated a higher percentage of fast-twitch fibers, the mean fiber area was greater, and selective fast-twitch fiber hypertrophy was evident. A body builder's training regimen is characterized by intense, repetitive contractions. Normally, a certain muscle group is exercised separately by 6-12 contractions until concentric contraction failure. Interspersed with short recovery periods, three sets or more are often repeated. This exercise is usually followed by or combined with additional exercises which activate the same muscle group. Accordingly, as many as 20 consecutive sets stressing a certain muscle may be executed within 30 minutes. This type of regimen is distinctly different from the typical training (low repetition system) that competitive power lifters rely upon (1982).

The number of sets and repetitions utilized should be sport specific. Correctly overloading not only specific energy systems, but correct muscle groups is crucial. Many sports such as football, basketball, weight lifting, track and field, etc. place great demands on the lower extremities. The legs are required to employ explosive strength during these activities (Charniga, 1985). It is recognized that speed, strength, acceleration, and agility are the prime elements essential for success in football (Stone & Kroll, 1978). Leg power is directly responsible for speed, acceleration, agility, and to a great extent, overall strength. Hence, leg power development is crucial if body speed, acceleration, agility, and overall strength are to be enhanced.

Since leg power is a critical aspect of football performance. Much attention is given to leg strength development in various supplemental weight programs. A lot of popular isotonic leg strength exercises (e.g., squat, leg extensions, hamstring curls, and heel raises) used in various strength programs, at all levels of competition, are done using both legs simultaneously (bilaterally). In compliance with specificity in training concepts, those bilateral leg training exercises should be consistent with corresponding muscle groups and movement patterns exhibited in skill execution. Few movement patterns in football resemble bilateral leg action in skill execution. Instead, unilateral (legs working independently) movement patterns are predominate. Thus, unilateral leg exercises should be incorporated in a good, comprehensive supplemental strength training program for football.

Research has indicated that bilateral leg extension force output is lower than summed unilateral extensions. Secher, Rosgaard, and Secher (1978) did a study where the force of maximal voluntary contraction (MVC) was compared during extension of one leg alone and during simultaneous extension of both legs. In their six subjects, MVC of the bilateral leg extension was 75% $\pm$ 3.6 of the sum of unilateral leg MVC. They hypothesized that these results indicated a reduced muscle fiber involvement in bilateral leg extension compared to unilateral leg extension. They tested their hypothesis by partially blocking neuromuscular transmissions to the motor units. They used d-tubocurarine (dtc) to block slow-twitch units and decamethonium (C_{10}) to block fast-twitch units. During administration of dtc the ratio between the reduced two leg and one leg extension forces (75% $\pm$ 2.3) did not change. When C_{10} was administered, however, this ratio decreased by 16% $\pm$ 3.1. Thus, partial blocking with C_{10} results in muscle contractions where a relatively large number of slow-twitch fibers are contributing to the force developed. The fact that bilateral force output is lower than the summed unilateral force output was also supported in studies by Coyle et al. (1981); Vandervoort, Sale, and Moroz (1984); and additional investigations of Secher (1975); Secher, Rorsgaard, and Secher, (1976); and Rube, Secher, and Lodberg, (1980).

Instead of dealing with the bilateral versus unilateral force output differences and the implications the differences show, some researchers (Howard et al., 1985) expressed a need to intensify the bilateral contractions during exercise to eliminate this bilateral strength deficit. This seems counterproductive unless the specific sports skill calls for bilateral leg movement. Secher's (1975) investigation is often cited as a basis of this concept. In his investigation, Secher studied three groups of oarsmen. Group one was a highly trained, international rowing club. Group two was the national club, not trained to the level of Group one. Group three was alocal club that was moderately trained. When MVC was tested bilateral and unilateral leg extensions, group one's bilateral MVC was 101% of the summed unilateral extensions, group two's was 95%, and group three's was 92%. Bilateral leg extension is inherent in rowing. This study indicates the need for oarsmen to train bilaterally to improve performance, thus, reinforcing the "specificity to training" concept. To extrapolate these results to the general population of athletics might be misleading.

Another study reinforcing specificity and the significance of habituation training toward skill enhancement goals was done by Rube, et al., (1980). Their investigation studied the effect of the habituation and training on two-legged and one-legged extension strength. They based their study on evidence (Secher, 1975; Secher et al, 1978) supporting the idea that determinations of the ratio (Ra) between MVC of extending both legs simultaneously and MVC of the two legs working independently, show that untrained subjects are unable to develop their full muscle strength during extension of both legs, when they are working together. The focus of their investigation was to determine whether the low Ra - value of untrained subjects was due to a lack of habituation or a lack of training. Their results suggested that the low Ra - value of untrained subjects reflects a relative impairment of the motoneurons when the legs are used simultaneously, but that the impairment vanishes with habituation.

Regarding bilateral versus unilateral leg strength, it has been established that there is a bilateral strength deficit when bilateral MVC is compared to the summed unilateral MVC. An exception to this seems to be individuals highly trained in bilateral-specific activities and exercises. In an attempt to explain the apparent strength deficit in bilateral training, Vandervoort, et al., (1984) compared motor unit activation during unilateral and bilateral leg extensions. They studied this phenomenon for several reasons. First, up to that point, they knew of no published electromyographic data illustrating that lesser motor unit activation in the bilateral (BL) vs. unilateral (VL) condition was responsible for the BL strength deficit. Second, if this was indeed the mechanism, the question of which type of motor unit is not recruited during the BL MVC needed further examination. Vandervoort et al. referred to the study done by Secher et al. (1978), which was described earler, as being inaccurate because the drugs used to block fast-twitch and slow-twitch fibers has not been conclusively determined to be effective in mixed human muscles. This led the researchers to discredit Secher's et al. conclusion that slow-twitch unit activation was reduced in the BL condition at a time when fast-twitch (FG and FOG) units were utilized. They suggested that this conclusion seems inconsistent with the orderly recruitment hypothesis of motor unit activation (Henneman, 1957). In their actual investigation they examined possible differences between the extent of muscle utilization during leg extensions performed bilaterally and unilaterally in young males in college. Significantly less integrated electromyographic activity was recorded from the quadriceps muscles of the dominant leg during BL compared with UL maximal voluntary contractions. They found that BL MVC was significantly lower than the summed UL MVC. It was shown also that the effect of increasing the velocity of concentric contraction was significantly greater on BL than UL force development; hence, at 424 degrees/sec. mean BL MVC was only 51% $\pm$ 3.5 of UL. Greater resistance to fatigue was shown in the BL condition in repeated concentric contractions. Their results indicated that the extent of motor unit activation seemed to be reduced in BL relative to UL MVC. Compatible evidence from the strength-velocity and fatiguability comparisons suggested that this decrease was due to a lower utilization rate of fast-twitch fatiguable type (FG) of motor unit. Their conclusions were that the strength of BL MVC in leg extension movement was less than the summed UL strength in isometric and concentric contractions. The greater relative decline in strength at high speed, in combination with lesser fatiguability in the BL condition, supported their hypothesis that there is reduced fast-twitch unit activation in BL MVC. Since football requires a high percentage of fast-twitch fiber utilization, maximum overload training of these fiber-types seems critical. Furthermore, unilateral leg movements are predominate in almost all performance-related skills. On the basis of this research, UL training for football might be advantageous.

Summary

To achieve and assure continued success, an athlete must both practice the skills and strategies used in game conditions and carry out a physical conditioning program. An integral part of a good conditioning program is strength training.

Muscular strength, power, speed, and endurance are important in almost all sports. Strength development is essential if power, speed, and endurance are to be increased to potential. Strength is increased via four types of muscular contractions: isotonic, isometric, eccentric, and isokinetic. Isokinetic exercises have proven to be superior in improving force-velocity output. However, because of the relatively expensive exercise and testing machines required for isokinetic training and the popularity of free weights, isotonic programs are utilized more than isokinetic programs.

Strength improvement hinges on both neural and muscular factors. The foundation of contractile strength is the motor unit. Force output results from two mechanisms involving motor units: rate coding and recruitment. Rate coding is the frequency with which motor units exhibit action potentials. Recruitment refers to the order of, the amount of, and the type of motor units activated during a specific contraction.

Motor units are classified according to speed of contraction, magnitude of force exerted, and resistance to fatigue. The three types of motor units are SO (slow-twitch oxidative), FOG (fast-twitch oxidative glycolytic), and FG (fast-twitch glycolytic). SO units are slow-contracting, exert the least force, and are fatigue resistant. FOG units are fast-contracting, exert immediate force, and are fatigue resistant. FG units are fast-contracting, capable of exerting high force, and are quick to fatigue (Edgerton, 1976).

Strength development seems to be dependent on both neural adaptations (rate coding and recruitment of motor units), and increased cross-sectional area of muscle fibers (hypertrophy). The mechanisms responsible for hypertrophy are unclear. There are, however, basic hypotheses that are generally adopted regarding causes of hypertrophy.

They are: (Fox & Mathews, 1981, p. 146).

(1) increase in size and number of myofibrils,

(2) increased amount of contractile protein,

(3) increased capillary density per fiber, and

(4) increased strength in tendons, ligaments, and connective tissue.

There is evidence that various individuals have different percentages of SO, FOG, and FG units. These percentages do not change due to various types of strength training programs. These percentages are based primarily on heredity (Fox, 1979). There is evidence that sport-specific strength training can stimulate optimum recruitment and rate coding of the motor unit type that is overloaded.

The ability to develop high power output is very important to the success of an athlete in almost any sport. If one were to choose a sport where power is the prime factor in success, football would be high on the list (Fox & Mathews, 1974). Speed, strength, acceleration, and agility are essential in football, therefore, leg power development is crucial in a supplementary strength training program.

Isotonic weight programs are based on the well-established and proven principles of overload, progression, specificity in training, sets and repetitions. Sport-specific strength programs must not only tax specific muscle groups that correspond to skill in performance, but must utilize congruent movement patterns in the various exercises.

Many isotonic programs incorporate the squat, leg extension, hamstring curl, and heel raise exercises for leg strength development.

These exercises are primarily done using both legs simultaneously (bilaterally - BL). However, most movement patterns in football are such that the legs work independently (unilaterally - UL).

Several studies have determined that in a maximal voluntary contraction (MVC), BL leg force output is less than the summed UL leg force output (Secher et al., 1978; Coyle et al., 1981; Vandervoort et al., 1984; Secher et al., 1976; Rube et al., 1980), except in a group of individuals who were initially highly trained in a BL leg extension-type sport (Secher, 1975). The reason for this BL strength deficit seems to be that there is less motor unit activation in the BL maximal voluntary contraction. There is also evidence to support the hypothesis that there is reduced fast-twitch unit activation in BL MVC, due to the fact that in the BL condition there was a greater relative decline in strength at high speed in combination with less fatiguability. UL training would seem to overload the FOG fiber-types (utilized a high degree in football) more intensely. In compliance with sport-specific training, it would seem that unilateral strength developing exercises might yield better results on the playing field.

In testing for power, strength, and speed, valid and reliable tests were utilized. Margaria, et al. (1966) published an article that recognized the need for a valid and reliable test of anaerobic power and proposed a test in which a subject was timed running up stairs (a distance the subject could attain in under five seconds). An equation was calculated to determine maximal anaerobic power based on time and distance (height climbed). Later, Kalamen (1968) investigated Margaria's equation and testing methods. Kalamen modified the test to further enhance validity and reliability. Based on his findings, Kalamen concluded that the modified Margaria power test (Margaria-Kalamen power test) was highly valid and reliable since it included the component of body weight in the equation, maximum anaerobic power was definitely achieved, and that it was practical and possible to predict potential success in athletics.

Both the hipsled (strength) and the 40-yard dash (speed) have long been recognized in football as valid and reliable tests. If done consistently, the hipsled is an ideal instrument to both test and train for strength development. The hipsled utilization requires almost no skill learning and strictly isolates the leg muscles without bringing the back muscles into play.

Almost all college programs utilize the 40-yard dash test as a valid means of assessing speed. Likewise, professional scouts commonly use the test as a way of evaluating potential draft choices. Quite often the success of a football player is recognized to be related to his 40-yard dash time. There are certainly exception to this rule, but they seem to be few.

Chapter 3

This chapter will describe the methods and procedures used to investigate bilateral vs. unilateral isotonic leg strength training and the ensuing efforts on leg power, strength and speed. The target population, sampling procedures, instrumentation utilization, test validity and reliability, procedures and methodology of data collection, and the method used for the statistical analysis of the data are all described in this chapter.

Target Population

The subject pool that was used for this study consisted of all Emporia State University football players that participated throughout the 1985 season and who participated in the off-season supplemental strength program that followed. It is important to note that although this intact group was in relatively superior condition in regard to the general college-age male population, this study assumed that within this intact group was a relative conditioning difference congruent to other college football program populations with physically similar individuals participating.

This study attempted to generalize its results to the populations of college football players in the Central States Intercollegiate Conference, with the possible exception of Washburn. This generalization is based on the type of athlete successfully recruited by most of the schools of the CSIC. Each school is a member of the National Association of Intercollegiate Athletics (NAIA), Division I. Each school has relatively the same size of enrollment. Each school is relatively similar in geographic location. With the exception of Washburn, each school is a public regional institution with relatively similar amounts of scholarship aid available.

Sampling Procedures

The subject pool consisted of 52 participants. In accordance with the randomized Solomon four-group design (detailed in the "Procedures and Methodology of Data Collection" section of this chapter), the group of 52 subjects was divided randomly by drawing names from a hat, into four subgroups. The subject pool of 52 was selected from the total group of 69 participants in the E.S.U. off-season conditioning program. (The 17 individuals who did not participate in this study either were new to the program and had not participated in the previous Fall season, or were deemed unfit by the athletic trainer to participate in a strenuous comprehensive leg strength training program.) Of the group of 52 who participated in the study, 10 subjects had to discontinue the treatment due to various injuries or ailments resulting from the football running program which all subjects participated in on the off lifting days. All of the subjects signed an Informed Consent Form (Appendix C) before taking part in the study.

The focus of the study was to investigate differences in the changes in leg power, strength, and speed. Inherent in both experimental and control group conditioning programs was strength conditioning via progressive resistance strength training. The control groups participated in the existing off-season conditioning program which included the bilateral squat, leg extension, hamstring curl, and heel raise exercises (Appendix D). The experimental groups participated in an alternate off-season program which included the unilateral step-up, lunge, and stationary running (Appendix D). The Margaria-Kalamen leg power test, hipsled 1 RM (repetition maximum) test, and 40-yard dash test was used to measure changes in leg power, strength, and speed respectively, as a result of the treatment of each group.

Validity, Reliability of Instrumentation and Testing Procedures

The testing was done at the weight training facility, the track, and the west grandstand of Welch Stadium on the campus of Emporia State University. A pre-test instruction sheet (Appendix I) regarding nutritional intake, amount of sleep the night before testing, extraordinary physical exertion, test time, test site, and proper attire, was given to the subjects two days prior to testing. On test day the subjects reported to the designated testing area dressing in proper attire. Each subject completed a pre-test questionnaire regarding injury or illness, nutritional intake, amount of sleep the previous night, and extraordinary physical exertion, to determine whether each subject's test score could be used as a valid representation of a maximal effort based on his physical condition. The subjects were then led through a series of flexibility exercises to stretch the various muscle groups of the body. The subjects then went through brief jogging and sprinting exercises to conclude the warm-up phase. It is also important to note that after testing was completed each day the subjects were again led through the flexibility routine to end the workout with proper cool-down.

Testing was done over a three day period. Two days were utilized for testing with one day in between to assure adequate recovery. The subjects were randomly divided into two groups prior to test day by drawing names from a hat. After the conclusion of the warm-up phase on the frist test day group A went to the weight room for the strength test. Group B went to the Margaria-Kalamen (M-K) testing area. After group B completed the M-K test they went to the 40-yard dash area. This completed the first day of testing. The second day of testing was completed in the identical manner, except that group A tested in the M-K and 40-yard dash and group B strength tested.

To enhance validity, groups A and B tested in the same order for both (pretest and posttest) testing periods. The same test administrators were used at the identical testing stations not only throughout the two-day testing session, but for both the pretests and the posttests.

The M-K power test (Appendix E) was utilized in determining leg power in the subjects. This test was selected because it is considered a valid and objective measurement of anaerobic power pertaining to sprint-like activities (Semenick, 1984; Kalamen, 1968). The individuals were first weighed in their shoes and all other clothing worn during the testing (for use in the M-K test equation). The test administrator explained the nature of the M-K test to the subjects, and why it is a valid test of power. The administrator also demonstrated the test. The subjects began by standing 6 meters in front of a staircase. At their pleasure they ran up the stairs as rapidly as possible, taking three stairsteps at a time. A switchmat was placed on the third and ninth steps (an average step is about 174 mm high). The clock on a Dekan timer started as the subject stepped on the first switchmat (on the third step) and stopped as he stepped on the second (or the ninth step). Time was recorded to a hundredth of a second. Three trials were given each subject with at least a three minute rest between trials (waiting in line). (Immediately following each trial was given, only to him, as feedback). Verbal encouragement was given to each subject by the test administrator. Each subject's weight and lowest time of the three trials were recorded on the data collection sheet (Appendix Q) for use in the M-K power formula. The vertical distance between the switchmats was measured prior to testing. Power output was computed using the formula:

$$P = \frac{W \times D}{t}$$

in which P = Power

W = Weight of person (fully clothed in testing attire)

D = Vertical height between first and last test steps

t = Time from first to last test steps

Objectivity was enhanced due to the use of switchmats. Since the time was measured to hundredths of a second, a greater difference between trials was recorded. Three trials were given the subjects to assure that the time used in the equation computation (best of three trials) was their best performance. The subject's test anxiety was reduced since the subject could begin the trial at his leisure.

The strength test was administered in the weight training facility at Welch Stadium. One repetition maximum (RM) on the hipsled (Appendix F) was used to determine leg strength. The hipsled is a commonly used machine for developing and testing strength in an isotonic program. The hipsled 1 RM test was selected because neither the experimental groups or the control groups utilized it during the treatment period.

The subject was asked to get in the hipsled so the chain could be set. (The chain length determines the angle the knees are bent when beginning the exercise). The chain length was set and recorded per individual, so that the knees were bent at a 90 degree angle when the repetition began. The subject's squat max (maximum left) was already known from a prior (four weeks) squat max which was done as part of the E.S.U. football off-season testing program.

Two weeks prior to the pretest period, a mini-study was done with five individuals to determine a comparison of hipsled and squat max. This was done so the test administrator would have an idea of hipsled max compared to a known squat max during the pretesting period. This helped to determine warm-up percentages prior to maximum lift attempt. The mini-study found that the hipsled max was between 120 and 130% of the individual's squat max.

Once the subject's appropriate chain length was determined, the amount of weight to use in the max warm-up phase was determined. The weight resistance progression was designed so the subject would reach 120% of his squat max on his fifth set. Repetitions per set were 10, 5, 3, 1, 1 (1 RM) with resistance percentages per set of 50, 65, 75, 85, 100% respectively. These figures are based on percentage charts determined by Bill Allergeiligan, Houston Oiler strength coach (personal communication, April 11, 1986) - (Appendix G, workout #7). Verbal encouragement was given each subject throughout his testing. The greatest amount of weight successfully lifted was recorded for analysis (Appendix Q).

The speed test used was the 40-yard dash. This was done on the Welch Stadium track. Forty yards was marked out on the track. The subjects ran in pairs with two administrators located at the finish line, timing each with a hand-held stopwatch. The subjects assumed a three-point football stance with their down-hands behind the starting line. They would start on command from a third administrator located at the starting line. On command the subject sprinted maximally through the finish line. The timers started the watches when the subject lifted his down hand, and stopped the watch when the subject's rum crossed the finish line. The subjects then walked back to the starting point, ensuring at least a three minute rest period between trials to stimulate ATP-PC replenishment. Three trials were given each subject. To enhance validity, the subjects switched lanes between trials so that their times were measured by both timers. Verbal encouragement was given to the subjects during testing. Immediately following each trial their time was told to them to provide feedback. All three times were recorded on a data collection sheet (Appendix Q).

For additional validation of the study regarding the strength test and treatment phase, the bars, plates, and collars were weighed on the scales of the Emporia Wholesale Coffee Company to certify the exact amount of weight used in the exercises. There was a .0039 percent of error found in the weight equipment. The same plates, collars, and bars were used during each session throughout the treatment period. The subjects were supervised at all times throughout the treatment period.

Procedures and Methodology of Data Collection

Research Design

The nature of this study was to investigate a possible difference in a relationship by exposing two experimental groups to a treatment and comparing the results to two control groups not receiving the treatment. This study attempted to control as many independent variables as possible, however, there were variables that could not be controlled due to certain limitations.

Due to the small number of subjects used in this study, the randomized Solomon four-group design was utilized to enhance validity (Isaac & Michaels, 1982).

Randomized Solomon Four-Group Design

Group	Pretest	Treatment	Posttest
1 - Pretested (R)	T_1	X	T_2
2 - Pretested (R)	T_1	.	T_2
3 - Unpretested (R)		X	T_2
4 - Unpretested (R)		.	T_2

The randomized Solomon four-group design overcomes the external validity weakness of the control-group pretest-posttest design, that being pretest sensitization. Pretest sensitication is a phenomenon in which a subject alters either their treatment or posttest performance based on their pretest performance. Since the four groups were selected randomly, the assumption could be made that the pretest scores of the unpretested groups are similar to the pretested groups. But since they were not pretested, no interaction between the treatment and the effects of the pretest can be reflected in the pretest scores.

The randomized Solomon four-group design permits the control and measurement of both the main effects of pretesting and the interaction effects of pretesting and the treatment, thereby enhancing validity (Isaac & Michaels, 1982).

Field Procedures

The four randomized groups were designated C_1, C_2, E_1 and E_2, in which C_1 was the pretested control group; C_2 was the unpretested control group; E_1 was the pretested experimental group, and E_2 was the unpretested experimental group. The M-K, strength, and speed test were administered to C_1 and E_1 prior to treatment. The pretest and posttest procedures were discussed earlier.

The treatment phase lasted six weeks, beginning immediately after a five-week period (Christmas break) without weight training. C_1 and C_2 participated in the strength training program utilized by the E.S.U. football team during their off-season. E_1 and E_2 participated in the same program with the exception of exercises specifically designed to strengthen leg muscle groups. The subjects worked out every Monday, Wednesday, and Friday. Examples of daily workout exercises for both experimental and control groups can be found in Appendix D. Included in the C_1 and C_2 daily schedule were four exercises that specifically overloaded the legs (the squat, leg extension, hamstring curl, and heel raises). It is important to note that all the exercises used to overload the leg muscle groups (in both control and experimental groups), and the manner in which they were done, were specifically designed to stimulate strength" gain. Since velocity of movement was not stressed, any specific "power" development was based on "strength" gains.

The squat workout (Appendix J) was composed of six sets of repetitions that decreased in number as the sets progressed, but increased in resistance. This was based on the principle that progressively increasing resistance and decreasing repetitions throughout the workout will cause various neuromuscular adaptations, gradually leading up to maximal resistance training. The leg extension (Appendix K) was done bilaterally. The subject did three sets of 8-12 repetitions. The subject adjusted the resistance so that he experienced muscle failure between 8 and 12 repetitions each set. The hamstring curl (Appendix L) was a bilateral exercise that also utilized the three set, 8-12 repetitions regimen. The bilateral heel raise (Appendix M) was an exercise that utilized a three set, 20 repetition routine. This type of workout indicated an emphasis on a more submaximal overload.

The experimental groups participated in the same program as the control groups with the exception of the squat, leg extension, hamstring curl, and heel raise exercises. E_1 and E_2 substituted the step-up, lunge, and stationary run exercises. The step-up exercise (Appendix N) was done on a bench that was 20 inches in height. The three set, six repetition theory (Palmieri, 1983) was utilized for the step-up routine. A "set" consisted of six consecutive step-ups with the right leg, then six consecutive step-ups with the left leg. The lunge

(Appendix O) also utilized the three set, six repetition theory. The stationary running exercise (Appendix P) was done in three sets of 40 exchanges each. An "exchange" was when one knee was brought up to the partner's hand. Somewhat inherent (varying in degrees from subject to subject) in the stationary running exercise was the velocity component. This has implications regarding "power" development whereas in the other exercises, speed of movement was not stressed.

The progressing of resistance in both control and experimental groups was individually based. As an individual felt he was proceeding through a workout with relative ease, he would increase the resistance.

Throughout the entire workout session of both the control and the experimental groups, emphasis was made on the need for adequate (at least 3-5 minutes) recovery periods between sets.

There was a relatively close relationship between the control program and the experimental program regarding overall work done per session. The total amount of weight lifted, when considering all of the sets, repetitions, and resistance amounts, during the control and experimental leg sessions per day was consistently within 15 percent. The amount of time it took each group to get through their respective workouts corresponded closely. This dispelled any notion of one group simply doing more work than another.

Data Analysis

A two-way analysis of variance (ANOVA) was used to determine the degree of variation each variable had on leg power, leg strength, and leg speed. A 0.1 level of significance was set to reject or accept the null hypothesis. If a significant difference was exhibited, Fisher's test of least significant mean (LSD) was employed to identify the location of the difference(s).

Substantive Hypothesis

The null hypothesis in this study was that there is no significant difference between a bilateral leg strength training program and a unilateral leg strength training program in their effect on leg power. The alternate hypothesis was that there is a difference between bilateral vs. unilateral leg strength programs and their effect on leg power.

Statistical Hypothesis

$H_0 = \mu C_1 = \mu C_2 = \mu E_1 = \mu E_2$

$H_A = \mu C_1 \neq \mu C_2 \neq \mu E_1 \neq \mu E_2$

Chapter 4

This chapter contains the results of the various data analysis techniques used in this study. Included is an explanation of data configuration methods used. Also included are the findings of the factoral two-way ANOVA analysis. Raw group means, standard deviations, and group T-score means for each test are included. The Fisher LSD test results for locating significant differences between treatment groups per test was also covered. The chapter concludes with a brief summarization of the data presented.

Data Configuration

In accordance with the randomized Solomon four-group design the mean posttest scores for each group was utilized in assessing performance. This design, by using a pretest component, allows the researcher to control the measure both the main effects of pretesting and the interaction effects of pretesting and the treatment.

The individual raw posttest scores were converted to a standardized T-score so that each type of measurement on the power, strength, and speed tests could be compared visually or directly. T-scores ($\bar{X} = 50$, $S = 10$) were used because they do not change the shape of the original distribution while magnifying minute differences in scores. T-score mean calculations were based on the deviations of the raw score grand mean of each treatment condition.

ANOVA

Table 1 illustrates the ANOVA results of the T-score group means. Tests were power, strength, and speed. Conditions were control group 1, control group 2, experimental group 1, and experimental group 2.

Table 1

Analysis of Variance of T-Means Between Tests, Between Conditions, and Interaction Between Tests and Conditions

Source of variance	Sum of squares	Degrees of freedom	Mean squares	F-ratio	Significance
Tests	10.149	2	5.074	0.73	
Conditions	515.325	3	171.775	2.485	.063*
Tests/Conditions Interaction	439.703	6	73.284	1.060	.391
Error	7880.632	114	69.128		

*significant difference

"Sum of squares (SS)" is referred to as the sum of the squares of the deviation scores. The SS column in the ANOVA source table (Table 1) is divided and illustrated per element (Tests, Conditions, Tests/ Conditions Interaction, and Error). The degrees of freedom column refers to the number of observations in each distribution that are free to vary. The "Mean of Squares (MS)" column represents the variance inherent in the population of scores (MS = SS/df). The F-ratio is formed by the ratio of two unbiased estimates of the variance (MS). The tabled value of F is derived by utilizing the degrees of freedom of effect (df among groups), the degrees of freedom of error (df within groups) and the level of significance (α). (The significance column refers to the mathematical difference between designated measures.)

The primary purpose of this statistical analysis was to determine significance between groups regarding treatment conditions. As just mentioned, "significance" refers to a mathematical measure of difference or association. The level of significance in this study was α=.10. The .063 significance value for the conditions source indicated there was significant difference demonstrated between treatment groups. This meant that somewhere in the analysis there was significant differences between two or more treatment groups on one or more of the tests.

Results of the Power Test

Table 2 indicates the raw group means, standard deviations, and group T-score means.

Table 2

Raw and T scores for Power

Treatment Group	Raw Mean (kg-meters/sec.)	Raw Standard Deviation	Mean T-score
C_1	177.62	19.55	50.98
C_2	177.41	14.36	50.88
E_1	166.07	23.18	43.60
E_2	181.37	19.05	52.84
All Subjects	175.62	20.26	50.00

Groups C_1 (pretest bilateral), C_2 (non-pretest bilateral), and E_2 (non-pretest unilateral) were relative consistent on raw score means. Group E_1 (pretest unilateral) scored dramatically lower. This indicated that pretest sensitization was not a factor in testing for power. Group C_2 demonstrated greater homogeneity while E_1 scores showed more variability.

Table 3 illustrates the use of Fisher's LSD method for determining significant differences between group T-score means on the power test. Fisher's least significant difference (LSD) technique was utilized in the identification of precise groups and tests signifying variance. The critical value for Fisher's LSD test ($\bar{d}_F$) for this study was $\bar{d}_F = 3.009$. Any variance of means ≥ 3.009 ($\pm$) was considered significant.

Table 3

Fisher's Determination of Mean Differences on the Power Test

	C_1	C_2	E_1	E_2
C_1	---	.10	7.39*	-1.02
C_2	---	---	7.29*	-1.12
E_1	---	---	---	-8.41*
E_2	---	---	---	---

*significant difference

Since $\bar{d}_F$=3.009, the results in Table 3 indicated that control 1 (pretest bilateral) scored significantly higher than experimental 1 (pretest unilateral). Likewise, control 2 (non-pretest bilateral) fared significantly better than experimental 1. Experimental 2 (non-pretest unilateral) also scored significantly higher than E_1. This indicated that C_1, C_2, and E_2 were all equal on their power test results while E_1 (pretest unilateral) was significantly lower.

Results of the Strength Test

Table 4 shows the raw group means, standard deviations, and group T-score means.

Table 4

Raw and T Scores for Strength

Treatment Group	Raw Mean (lbs.)	Raw Standard Deviation	Mean T-score
C_1	660.0	59.82	52.55
C_2	620.0	51.73	47.08
E_1	615.46	76.65	46.13
E_2	670.42	66.97	54.05
All Subjects	642.26	69.31	50.00

Table 4 illustrates equal group raw mean scores between C_1 and E_2 while E_1 and C_2 demonstrated lower scores. E_2 had the highest $\bar{x}$ and E_1 had the lowest. As in the power test results, C_2 indicated greater homogeneity and E_1 scores greater variability.

Table 5 indicates Fisher's LSD utilization for determining significant differences between group T-score means on the power test.

Table 5

Fisher's Determination of Mean Differences of the Strength Test

	C_1	C_2	E_1	E_2
C_1	---	5.47*	6.42*	-1.5
C_2	---	---	.95	-6.97*
E_1	---	---	---	-7.92*
E_2	---	---	---	---

* significant difference ($\bar{d}_F$=3.009)

Table 5 illustrates that C_1 (pretest bilateral) was significantly higher than C_2 (non-pretest bilateral) and E_1 (pretest unilateral) E_2 (non-pretest unilateral) scored significantly higher than C_2 and E_1. This meant that C_2 and E_1 exhibited less strength than both C_1 and E_2. This was not consistent with the power findings since there was no significant difference between C_2 and E_1 on strength, where there was difference on power.

Results of the Speed Test

Table 6 shows the raw group $\bar{x}$, s, and group T-score $\bar{x}$.

Table 6

Raw and T Scores for Speed

Treatment Group	Raw Mean (sec.)	Raw Standard Deviation	Mean T-score
C_1	5.24	.16	49.54
C_2	5.18	.37	49.87
E_1	5.07	.34	50.38
E_2	5.12	.27	50.17
All Subjects	5.15	.30	50.00

In an anaerobic speed test the difference between raw group $\bar{x}$ scores would be relatively close in a random sample as demonstrated in this case in Table 6. Using T-score means would enhance the differences in small differences. However, the T-score means in this case illustrated that all groups scored closely on the speed test. Group E_1 indicated the fastest $\bar{x}$ 40-yard dash time while C_1 was slowest. Control group 1 demonstrated greater homogeneity and C_2 showed the most variability.

Table 7 indicates the usage of Fisher's LSD technique for determination of significant differences between group T-score $\bar{x}$ on the speed test.

Table 7

Fisher's Determination of Mean Differences on the Speed Test

	C_1	C_2	E_1	E_2
C_1	---	-.33	-.84	-.63
C_2	---	---	-.51	-.3
E_1	---	---	---	-.21
E_2	---	---	---	---

There were no significant differences indicated between groups at the $\bar{d}_F$=3.009 level on the speed test.

Summary

In order to make group mean comparisons, the raw scores were transformed into standardized scores. T-scores ($\bar{X}$ = 50, S = 10) were used because the shape of the original distribution remained intact while minute differences were magnified. The factoral two-way ANOVA found that significant (α =.10) difference existed between two or more treatment groups on one or more tests. No significant difference was found to exist between interactions of tests and conditions (treatment groups). The Fisher LSD (least significant difference) technique was used to locate the significant differences.

It was found that on the power test C_1(pretest bilateral), C_2 (non-pretest bilateral), and E_2 (non-pretest unilateral) were significantly higher than E_1 (pretest unilateral) at the α.10 level. Therefore,

the null hypothesis of $H_0: \mu C_1 = \mu C_2 = \mu E_1 = \mu E_2$ was rejected and the alternate hypothesis of $H_A: \mu C_1 \neq \mu C_2 \neq \mu E_1 \neq \mu E_2$ was accepted. Furthermore, because E_1 was significantly lower, the pretest sensitization factor appeared to be nonexistent.

A significant difference was found between groups on the strength test. The C_1 and E_2 groups were consistent and were both significantly higher than C_2 and E_1. There was no significant difference between C_2 and E_1 on strength, but there was a significant difference between C_2 and E_1 on power. This result made it difficult to substantially associate scores on power and speed tests.

There was no significant differences between groups on the speed test. Therefore, there was no substantive association of speed differences to power differences. This result was consistent with the assumption that speed, to a great extent, is largely related to the heredity of an individual.

Chapter 5

Summary

This study was designed to determine differences in the effects of bilateral vs. unilateral leg strengthening exercises on leg power. Leg strength and speed were also tested to give insight into the power performance. Forty-two subjects were divided into four groups: (1) a pretest bilateral group (C_1); (2) a non-pretest bilateral group (C_2); (3) a pretest unilateral group (E_1); and (4) non-pretest unilateral group (E_2). C_1 and E_1 were pretested in power (Margaria-Kalamen power test), strength (hipsled 1 RM), and speed (40-yard dash). All subjects participated in a six week treatment program. C_1 and C_2 did bilateral leg strengthening exercises three times a week while E_1 and E_2 did unilateral leg strengthening exercises three times per week. After six weeks of treatment all the subjects were posttested on power, strength, and speed.

A factoral two-way ANOVA technique was used to measure both the variance in the conditions (groups) and the interaction of the conditions and tests. No significant differences were indicated on the interaction of the conditions and tests at the $\alpha = .10$ level. There was significant difference in the conditions. A Fisher LSD (least significant difference) test was used to locate the difference in the conditions. On the power test C_1, C_2 and E_2 were significantly different than E_1. This led to the rejection of the null hypothesis of $H_0: \mu_{C_1} = \mu_{C_2} = \mu_{E_1} = \mu_{E_2}$ and the acceptance of the alternate hypothesis of $H_A: \mu_{C_1} \neq \mu_{C_2} \neq \mu_{E_1} \neq \mu_{E_2}$. Furthermore low performance of E_1 on the power test disspelled the possibilities of pretest sensitization.

Significant differences in the strength test made it difficult to substantively associate group strength performance with their power performance. No significant differences were found to exist between groups on the speed test also making it difficult to draw substantive implications on power.

Discussion

The results of this study demonstrated that there was a directional difference in the two types of treatment regimens. According to this study's findings bilateral strength training exercises yielded greater power gains than unilateral strength training exercises. This supports Secher's (1975) results of his study on oarsmen. He found that relatively small differences occured between bilateral and unilateral strength tests in moderately trained oarsmen and that highly trained oarsmen exhibited greater force output on bilateral strength tests than they did on the summed unilateral tests. The subjects in this study (football players involved in off-season training) were considered highly trained in that they were involved in a lifting and running program five days per week.

Of concern in this study was the inconsistent results of experimental group one (pretested unilateral) on the power test. The difference exhibited by E_1 might be explained by a lack of motivation, an inherent overall power deficiency, or a combination of both.

Regarding the motivation factor, if a sample of sufficient size were drawn, the less motivated individuals' scores would not tend to sway the entire group mean. If the sample were drawn randomly, the less motivated individuals would tend to disperse homogeneously throughout the database. The possibility exists that n (11) was not large enough to exhibit true indication of the population. It was also the researcher's subjective observation that E_1 had an inordinately high percentage of individuals who did not attempt to reach maximal exertion during the treatment sessions.

Inherent overall power deficiency from individual to individual was to be expected. However, if random assignments were drawn, these less powerful individuals would tend to even out between groups. Again, n (11) size might have been a problem. Random sampling error tends to diminish when n increases.

Another source of error might have been the "John Henry" effect (Isaac & Michaels, 1983). This occurs when the members of the control group(s) discover their status and are extraordinarily motivated to out-perform the experimental group(s). The bilateral groups could have been motivated to work harder.

True indications of leg power, strength, and speed also may not have been exhibited due to the additional intensive off-season conditioning program the subjects participated in. During the treatment period the subjects were involved in agility and plyometric drills twice a week (on off-lifting days). Complications resulted in the form of shin splints and other various ailments. Ten of the original subjects had to be dropped from the study due to these ailments. This intensive comprehensive leg conditioning program might have altered true indications on the power, strength, and speed tests due to chronic fatigue.

Another area of concern was the unilateral stationary running exercise. The subjects expressed lower back discomfort. The discomfort was not severe enough to warrant discontinuation in most cases.

In subjective evaluation regarding strength and power gains, it was observed through various comments that a greater degree of muscle soreness was experienced by the experimental groups. This could have been due to inherent eccentric qualities of the unilateral exercises that were not present in the bilateral exercises. Perhaps related to this is the possible incorporation of a greater percentage of muscle fibers used to complete the exercises as Vandervoort et al. (1984) suggests. It was also subjectively observed that a relatively greater amount of hypertrophy occured in the experimental subjects at the three week point. However, the hypertrophy rate in the experimental groups seemed to decrease throughout the last half of the treatment period. This supports Hakkinen and Komi's (1983) suggestion that strength gains are experienced early in a conditioning program and then tend to taper off.

After the initial soreness period, the experimental subjects expressed that their legs "felt stronger" during daily activities. There could be two possible reasons why the experimental subjects felt this way to a greater degree than the control subjects. First, the unilateral training program coincided with Vandervoort's et al. (1984) findings that there is a greater percentage of fiber involvement in unilateral exercises. The second reason could be that since the unilateral exercises were new to the subjects, psychologically they liked the exercises and believed that they were experiencing greater strength gains when in actuality they were not.

The longevity of the study was of concern. The subject pool was considered well trained. (A six-week strength training program may not have been long enough for the subjects to make and display greater differences.) A treatment period of 10-12 weeks or longer might have yielded alternate results.

Recommendations

On the basis of the results of this study, the following recommendations are suggested for future investigations:

(1) The number of subjects used in this study was 42 (C_1 n=9; C_2 n=10; E_1 n=11; E_2 n=12). Although the statistical method in this study was valid, validity might have been enhanced using a larger n. A replication of this study using a larger n might yield alternate results.

(2) A six-week treatment period was used in this study. Due to the fact that these subjects were highly trained, six weeks might not be sufficient time for greater strength to develop. Similar studies might be done by either extending the treatment period, or utilizing a subject sample which includes a variety of physically conditioned individuals.

(3) Increased strength gains were subjectively noticed early in the treatment program. Future studies might utilize a test after a three week period as well as a pretest and posttest.

(4) Since lower back complications arose from this unilateral stationary running exercise, a substitute might be utilized in a similar study.

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Appendix A

Metabolic Considerations

Metabolic Energy Considerations

Adenosine triphosphate (ATP) is the immediately usable form of chemical energy for muscular activity. It is stored in most cells, particularly muscle cells. Other forms of chemical energy, such as that available from foods we ingest, must be converted into the ATP form before they can be utilized by the muscle cells (Fox, 1979). Since ATP is the only usable source of energy for muscle contraction, it must be resynthesized as it is expended through the duration of an activity. ATP is replenished by three different energy systems: (1) the ATP Phosphocreatine (ATP-PC) system, (2) the lactic acid (LA) system, and (3) the oxygen (O_2) system. Two of these three systems, the ATP-PC and LA, synthesize ATP anaerobically (without the presence of oxygen). The O_2 system synthesizes ATP aerobically (with oxygen present). The particular energy system utilized in ATP metabolism is dependent on the duration and intensity of the activity.

The ATP-PC System (Anaerobic)

Phosphocreatine (PC), which is stored in the muscle cells, almost instantly manufacture ATP, which is also stored in muscle cells, for energy utilization. The concentration of stored ATP is very low. The rate that PC replenishes ATP is relatively high. The amount of PC stored in the muscle is 3-4 times greater than that of ATP (Tesch, L984). PC is a particularly important source of energy during intense exercise of a short duration (less than 10 sec.) and at the onset of heavy resistance activity.

When the rate of ATP utilization is low, light exercise or resting conditions, ATP is used to replenish the PC stores back to normal levels.

During intense exercise and ATP utilization is high, PC is used to normalize ATP levels.

The drawback to this system is that only a small portion of ATP and PC can be stored in the muscle. The supply only lasts 10 seconds or less. However, it is well established that with 30 seconds of complete rest between intermittent bouts, approximately 50 percent of the ATP-PC that was depleted is restored, and relief intervals lasting two minutes or longer virtually replenish the entire amount of ATP-PC (Fox, 1979).

The advantage of the system is the high power output. Energy can be produced at a high rate. Activities usually associated with the ATP-PC system are those that require short bursts of "all out" efforts. Some of thses activities include blocking and tackling in football, 100 and 200 meter sprints, field events in track, powerlifting and quick, explosive movements in basketball and baseball.

Lactic Acid (LA) System (Anaerobic)

Lactate formation occurs at the onset of heavy exercise accompanying the breakdown of PC. When the high intensity exercise is continued, energy production through anaerobic breakdown of gylcogen to lactic acid becomes more and more important. This process, glycogenolysis, at maximal stimulation can theoretically only contribute to energy production for an activity period of less than 60 seconds duration (Tesch, 1984).

As lactic acid accumulates, and PC stores become depleted, the capacity to generate energy at the desired level ceases. Thus, the muscle becomes fatigued, resulting in diminished power output. The negative effects of lactate accumulation on power output are related to

(a) an associated drop in pH, resulting in enzyme inhibition, and (b) an increased concentration of hydrogen ions directly interfering with the actin-myosin cross-bridge formation (Tesch, 1984).

Energy production through glycogenolysis with its accompanying lactate formation yields more ATP. However, the power of the system is lower since the maximum energy-producting rate is lower. The 400 meter hurdler is in great need of having a high concentration of ATP-PC at the onset of exercise. Thus, energy release through glycogenolysis can be delayed. The longer the PC-store will last, the longer can greater speed by maintained by the runner. Hence, there are three limiting factors due to performance which requires the LA system: (1) resting PC stores, (2) capacity to generate energy at a sufficiently high rate, and (3) the ability to resist the fatiguing effects of lactate accumulation (Tesch, 1984).

The Oxygen (O_2) System (Aerobic)

In the presence of oxygen, the food man eats, especially carbohydrates and fats, provide fuel for constant production of ATP to be used by the muscle cells. The aerobic system is essential for man's continuous existence. It not only produces ATP most efficiently and abundantly but, it is also the prime source during "endurance" events -- 2-mile, cross country, and marathon performances (Fox, 1979).

Appendix B

Neuromuscular Considerations

Neuromuscular Considerations

The main component of the nervous system is the nerve cell, or neuron. There are essentially two types of neurons. The snesory neurons provide the central nervous system (brain and spinal cord) with intraorganism and environmental stimuli. The motor neurons provide stimuli from the central nervous system to the muscles causing muscular contraction and relaxation. This section will focus primarily on the motor neuron since muscular contraction is of greatest concern.

Most single motor neurons have many branches and thus, in entering a muscle, innervate many muscle fibers. However, a given muscle fiber is innervated by only one motor neuron. A motor neuron plus all the muscle fibers it innervates is called a motor unit (Fox, 1979). A single area of a motor neuron can branch from 15 to 600 times to connect to each of its muscle fibers, thus, the size of motor units vary (Howard et al., 1985).

Motor units function as they are stimulated by nerve impulses. A nerve impulse is simply electrical energy transferred through the neurological pathway. When the nerve fiber is at rest, sodium ions (+) surrounds the outside. The inside of the fiber has a negative charge. Upon stimulation of a nerve impulse, the nerve fiber membrane becomes permeable, allowing sodium ions to infiltrate the interior of the nerve. This process results in a positive charge inside the nerve fiber and is known as "reversal of polarity." Reversal of polarity is also known as "action potential." Action potentials in both nerve and muscle are "all-or-none" events. That is, once an action potential stimulates the motor unit, all the muscle fibers innervated in the unit will contact uniformly.

This all-or-none phenomenon does not apply to force production. According to Howard, et al. (1985), variations in force output are possible by way of two mechanisms at the motor unit level: (1) rate coding, and (2) recruitment. Rate coding refers to the frequency with which motor neurons discharge action potentials. Generally, as action potential frequency increases, force output increases. Regarding motor unit recruitment, not all motor units are initially stimulated with action potentials. As resistance intensifies, additional units are recruited. The units recruited first typically produce the lowest amount of force, while those activated later can exert a greater force. As force output increases to higher levels, the contribution of each additional unit to the total force is greater than at low force levels.

Within humans, there are two general types of motor units. There are slow or type I units, and fast or type II motor units. These motor units are basically similar in structure, but there are key differences that exist. The fast motor units can be categorized even further to fast oxidative glycolytic (FOG) or type IIa, and fast glycolytic (FG) or type IIb (Edgerton, 1976).

The type I (SO-slow oxidative) fiber has a greater aerobic capacity. The motor neuron is small, lightly myelinated (the myelin sheath surrounds the axon of a nerve cell, which is the structure that transmits impulses away from the nerve cell body), and has less membrane surface area. Type I units are recruited for less powerful, endurance type activity (Edgerton, 1976).

The type IIb fiber (FG), has a much greater anaerobic capacity than type I fibers. Type IIb fibers are innervated by a very large, heavily myelinated nerve that has more membrane surface area. Type IIb units are utilized for quick, powerful movements (Edgerton, 1976).

The type IIa fiber (FOG) is an intermediate fiber, whose outcome depends upon the way it is trained. The structure remains the same through training, but the enzyme activities are modified. Type IIa fibers remain consistent in that they are more fatigue-resistant than type IIb. Type IIa has a high tension output, although not as high as type IIb, and has a motor neuron size in between type I and type IIb. While these fibers can generate power, they can also continue for long durations. These motor units are needed for those activities that require power over an exercise bout lasting more than 60 seconds (Edgerton, 1976).

The human body consists of large muscle groups (e.g., back, legs, chest, stomach, arms, and shoulders). Each muscle group is made up of thousands of long, cylindrical muscle fibers that join with tendons at each end. Muscle fibers are composed of thousands of cylinderical myofibrils. In these myofibrils are thin protein filaments called actin, and relatively thick protein filaments called myosin. Actin and myosin lie parallel with each other. The muscle fibers are innervated by motor neurons. Muscular contraction is initiated by an impulse from the motor neuron which causes a cross-bridging of actin and myosin filaments. This causes a breakdown of ATP releasing energy that pulls the actin filaments along the stationary myosin filaments causing movement (dynamic contraction).

Appendix C

Informed Consent Form

INFORMED CONSENT FORM

I, Paul Miller, am requesting your participation in a study designed to estigate the effects of two types of off-season leg strength training grams on leg power, strength, and speed. As a participant in the study, will be asked to participate in one of four groups: Control Group 1, trol Group 2, Experimental Group 1, and Experimental Group 2.

The subjects in both control groups will participate in the Emporia University off-season strength training program. The subjects in experimental groups will follow everything in the E.S.U. off-season ength training program with the exception of substituting exercises for squat, leg extension, leg curl, and toe raises, for a six week period.

Half of the control group and half of the experimental group will be en pretreatment tests, including a strength test, a power test, and eed test. All subjects will participate in the six week treatment od. During the treatment period the subjects will be supervised and increase in the amount of workout repetition weight will be recorded. r the six week treatment, all of the subject in the study will be nistered the leg strength, power, and speed tests. The major objectives his study is power, strength, and speed development in the lower extremity le groups.

As in any weight training activity, there are injury risk factors. le strains and injuries due to falling weights may occur. Each subject be spotted through their exercises and a supervisor will be on hand elp minimize risk and assist in the case of an emergency.

Your permission to use the data described above is requested for use onducting research for a thesis. Your test scores will be recorded rding to your code number and all the data analyzed will be in terms of up averages" so your privacy will be assured. I will have the only ding sheet. If you have any questions concerning this program, please free to talk to me in person, or call me at home (316) 343-6978, or he HPER&A office (ext. 354).

"I have read the above statement and have been fully advised of the edures to be used in this project. I have been given sufficient rtunity to ask questions I had concerning the procedures and possible s involved. I understand the potential risks involved and assume them ntarily. I likewise understand that I can withdraw from the study at time without being subjected to reproach."

ect's Signature   Date

Appendix D

Example of Workout Session for Control and Experimental Groups

1986 E.S.U. FOOTBALL TEAM
STRENGTH TRAINING
Friday, February 7, 1986

Squat - Workout Number: 4

Leg Extension - Three Sets of 8-12

Leg Curl - Three Sets of 8-12

Heel Raises - Three Sets of 20

Bench Press - Workout Number: 4

Incline Dumbbell - Two Sets of 8-12

Flatback Flys - Two Sets of 8-12

Behind the Neck Shoulder Press - Workout Number: 4

Upright Row - Two Sets of 8-12

Lat-Pull - Two Sets of 8-12

Back Extensions - Two Sets of 15

Sit-Ups - Two Sets of 33

Neck - Two Sets of 8-12

Dips - Two Sets of 10-20

Arm Curls - Two Sets of 8-12

Pull-Ups - One Set Until Exhaustion

*Jog two laps and stretching routine before lifting

*Run loop and stretch after lifting

1986 E.S.U. FOOTBALL TEAM
STRENGTH TRAINING
Friday, February 7, 1986

Step Ups - Three Sets of 6 per leg

Step Outs - Three Sets of 6 per leg

Stationary Running - Three Sets of 20 each leg

Bench Press - Workout Number: 4

Incline Dumbbell - Two Sets of 8-12

Flatback Flys - Two Sets of 8-12

Behind the Neck Shoulder Press - Workout Number: 4

Upright Row - Two Sets of 8-12

Lat-Pull - Two Sets of 8-12

Back Extensions - Two Sets of 15

Sit-Ups - Two Sets of 33

Neck - Two Sets of 8-12

Dips - Two Sets of 10-20

Arm Curls - Two Sets of 8-12

Pull-Ups - One Set Until Exhaustion

*Jog two laps and stretching routine before lifting

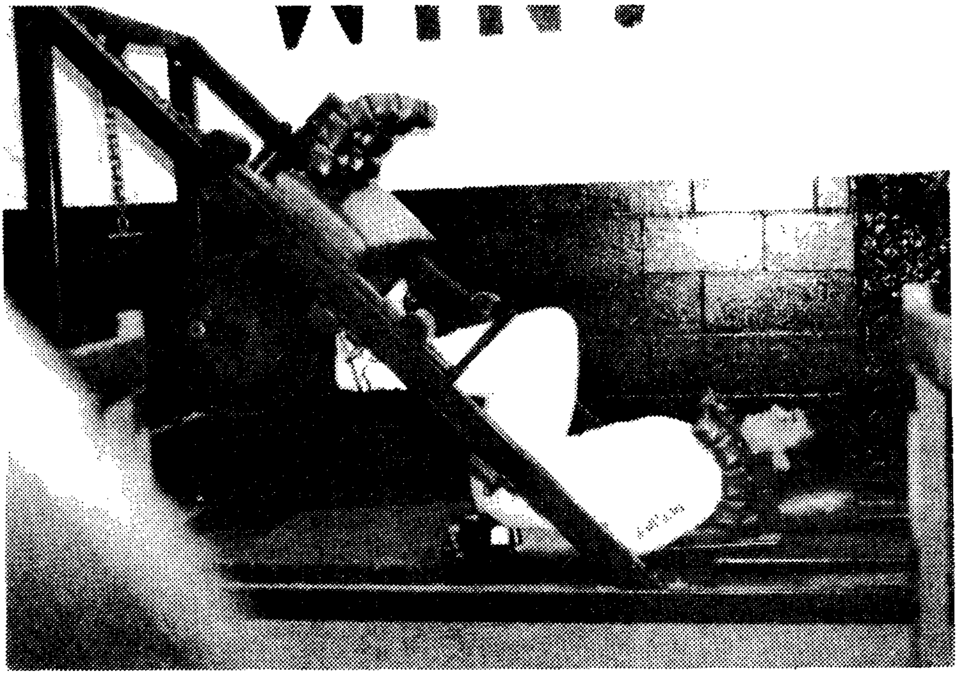
*Run loop and stretch after lifting

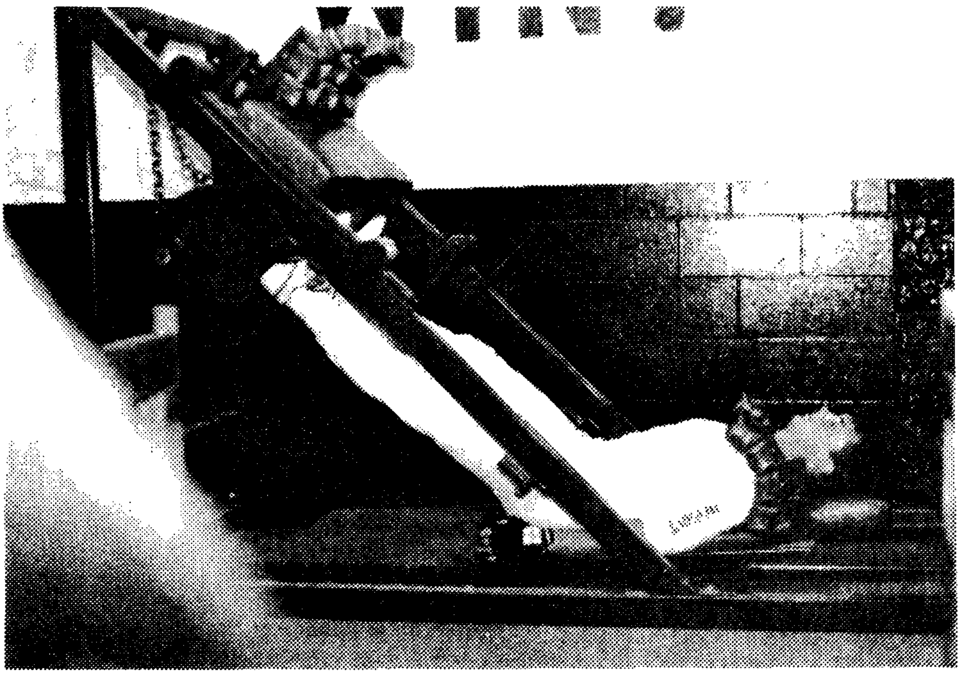
Appendix E

The Margaria-Kalamen Power Test

Appendix F

The Hipsled Exercise





The subject begins with the thighs and shins at a 90° angle. The subject pushes the footrest (with the weight) up until the knees are locked. This is one repetition.

Appendix G

Allerheiligan Percentage Set and

Repetition Chart

MAX.	WORKOUT #1		#2		#3		#4		#5					
360	10x175 10x200 10x220	10x240 10x265	10x175 8x200 8x220	8x240 8x265 8x285	10x175 8x220 6x240	6x265 6x285 6x305	10x175 8x240 6x265	4x285 4x305 4x330	10x175 8x265 6x285	4x305 2x330 2x350	10x175 8x275 6x295	4x315 2x340 1x360	10x175 5x230 3x275	1x305 1x340 1x370-375
365	10x180 10x200 10x225	10x245 10x265	10x180 8x200 8x225	8x245 8x265 8x290	10x180 8x225 6x245	6x265 6x290 6x310	10x180 8x245 6x265	4x290 4x310 4x330	10x180 8x265 6x290	4x310 2x330 2x355	10x180 8x275 6x300	4x320 2x345 1x365	10x130 5x235 3x275	1x310 1x345 1x375-380
370	10x180 10x205 10x225	10x250 10x270	10x180 8x205 8x225	8x250 8x270 8x290	10x180 8x225 6x250	6x270 6x290 6x315	10x180 8x250 6x270	4x290 4x315 4x335	10x180 8x270 6x290	4x315 2x335 2x360	10x180 8x280 6x305	4x325 2x350 1x370	10x180 5x235 3x280	1x315 1x350 1x380-385
375	10x185 10x205 10x230	10x250 10x275	10x185 8x205 8x230	8x250 8x275 8x295	10x185 8x230 6x250	6x275 6x295 6x320	10x185 8x250 6x275	4x295 4x320 4x340	10x185 8x275 6x295	4x320 2x340 2x365	10x185 8x285 6x310	4x330 2x355 1x375	10x185 5x240 3x285	1x320 1x355 1x385-400
380	10x185 10x210 10x230	10x255 10x275	10x185 8x210 8x230	8x255 8x275 8x300	10x185 8x230 6x255	6x275 6x300 6x325	10x185 8x255 6x275	4x300 4x325 4x345	10x185 8x275 6x300	4x325 2x345 2x370	10x185 8x290 6x310	4x335 2x355 1x380	10x185 5x245 3x290	1x325 1x355 1x390-405
385	10x190 10x210 10x235	10x260 10x280	10x190 8x210 8x235	8x260 8x280 8x305	10x190 8x235 6x260	6x280 6x305 6x325	10x190 8x260 6x280	4x305 4x325 4x350	10x190 8x280 6x305	4x325 2x350 2x375	10x190 8x295 6x315	4x340 2x360 1x385	10x190 5x245 3x300	1x325 1x360 1x395-410
390	10x190 10x215 10x240	10x260 10x285	10x190 8x215 8x240	8x260 8x285 8x310	10x190 8x240 6x330	6x285 6x310 6x285	10x190 8x260 6x285	4x310 4x330 4x355	10x190 8x285 6x310	4x330 2x355 2x380	10x190 8x295 6x320	4x345 2x365 1x390	10x190 5x250 3x295	1x330 1x365 1x400-415
395	10x195 10x215 10x240	10x265 10x290	10x195 8x215 8x240	8x265 8x290 8x310	10x195 8x240 6x265	6x290 6x310 6x335	10x195 8x265 6x290	4x310 4x335 4x360	10x195 8x290 6x310	4x335 2x360 2x385	10x195 8x300 6x325	4x350 2x370 1x395	10x195 5x255 3x300	1x335 1x370 1x405-420
400	10x195 10x220 10x245	10x270 10x300	10x195 8x220 8x245	8x270 8x300 8x315	10x195 8x245 6x270	6x300 6x315 6x340	10x195 8x270 6x300	4x315 4x340 4x365	10x195 8x300 6x315	4x340 2x365 2x390	10x195 8x305 6x330	4x350 2x375 1x400	10x195 5x255 3x305	1x340 1x375 1x410-425
405	10x200 10x225 10x245	10x270 10x300	10x200 8x225 8x245	8x270 8x300 8x320	10x200 8x245 6x270	6x300 6x320 6x345	10x200 8x270 6x300	4x320 4x345 4x370	10x200 8x300 6x320	4x345 2x370 2x395	10x200 8x310 6x330	4x355 2x380 1x405	10x200 5x260 3x310	1x345 1x380 1x415-430
410	10x200 10x225 10x250	10x275 10x300	10x200 8x225 8x250	8x275 8x300 8x325	10x200 8x250 6x275	6x300 6x325 6x350	10x200 8x275 6x300	4x325 4x350 4x375	10x200 8x300 6x325	4x350 2x375 2x400	10x200 8x310 6x335	4x360 2x385 1x410	10x200 5x260 3x310	1x350 1x385 1x420-435

Appendix H

Pre Test Questionnaire

PRE TEST QUESTIONNAIRE

NAME ______________________________

Approximately how many hours ago did you have your last meal?

Approximately how many hours of sleep did you have last night?

Are you feeling ill today? _____Yes _____No

If so, what is the problem?

Do you have any injury that would hinder your performance in the 40 yard dash, running up 9 steps as quickly as possible, or maxing out on the hip sled? _____Yes _____No

If so, what is the problem?

Have you excersised out of the ordinary, with great intensity over the past 48 hours? _____Yes _____No

If so, what did you do and how long did you do it?

Appendix I

Pre Test Instruction Sheet

PRE TEST INSTRUCTION SHEET

In the next two days you will be given a test to measure your leg power, strength, and speed. It is very important that you do the best you can on this test. To assure optimum performance a few precautions must be taken. It is important that you follow these guidelines:

1. Do not do anything out of the ordinary that is extremely taxing to the leg muscle groups within the next 48 hours.

2. Get at least 7 hours of sleep the night prior to the test.

3. Do not alter your diet within the next 48 hours.

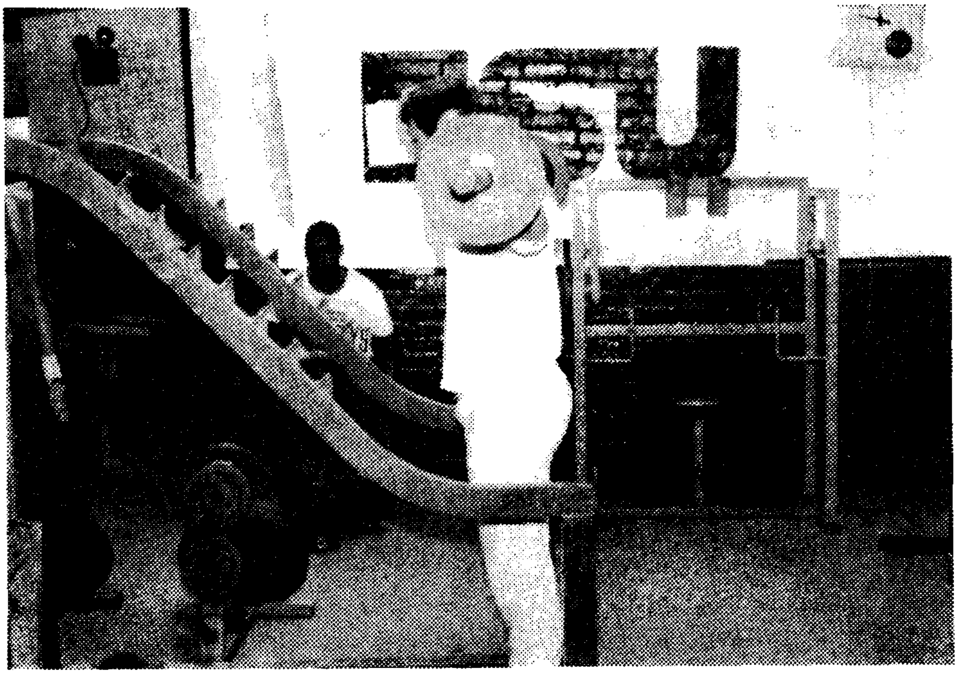
4. Be sure you eat your last full meal at least 3 hours prior to your designated test time.

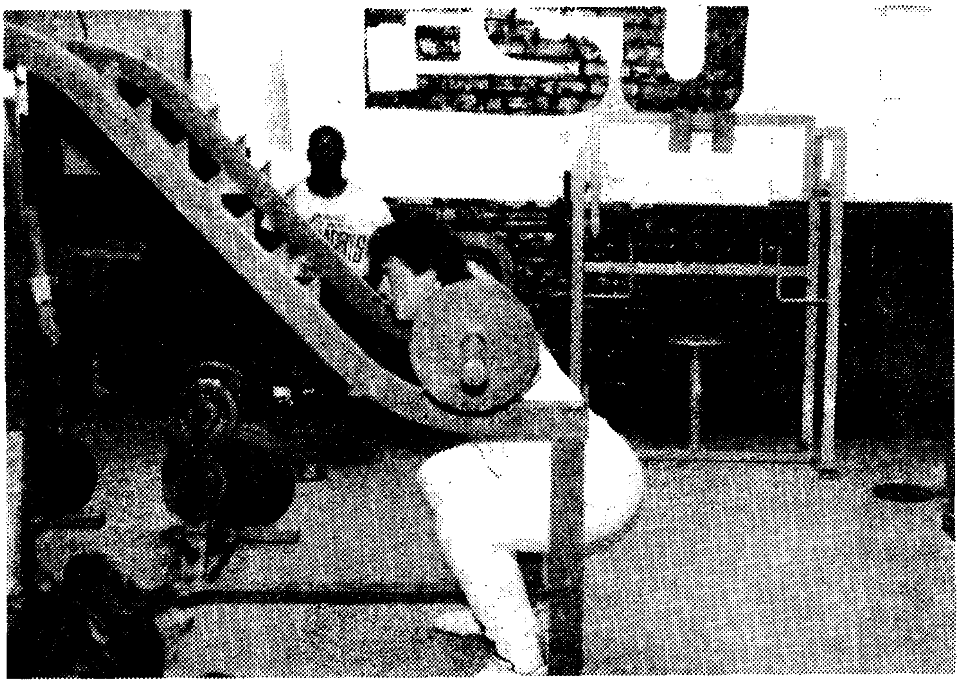
As stated earlier, these tests will measure leg strength, power, and speed. Since these three components are extremely important to a successful football player, the test scores are significant indicators. Any severe deviation from the four guidelines above could alter your test scores, thereby distorting the results of this study.

Your designated test time is ___________. The testing will take place at the Welch Stadium weight facility and the track. Report to the locker room and be dressed in your grays at your designated time.

Appendix J

The Squat Exercise

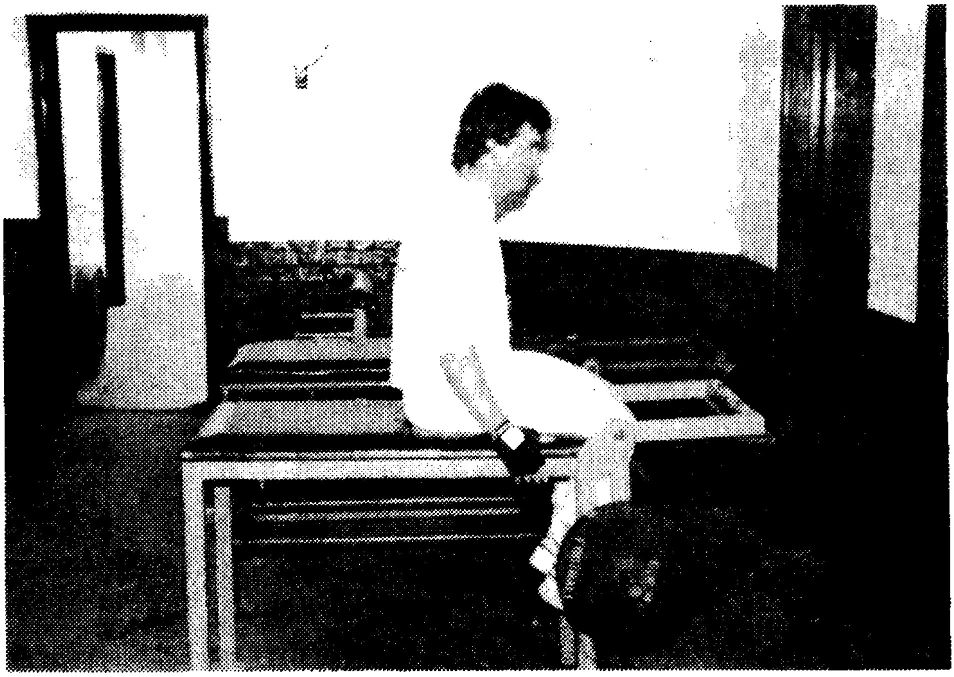


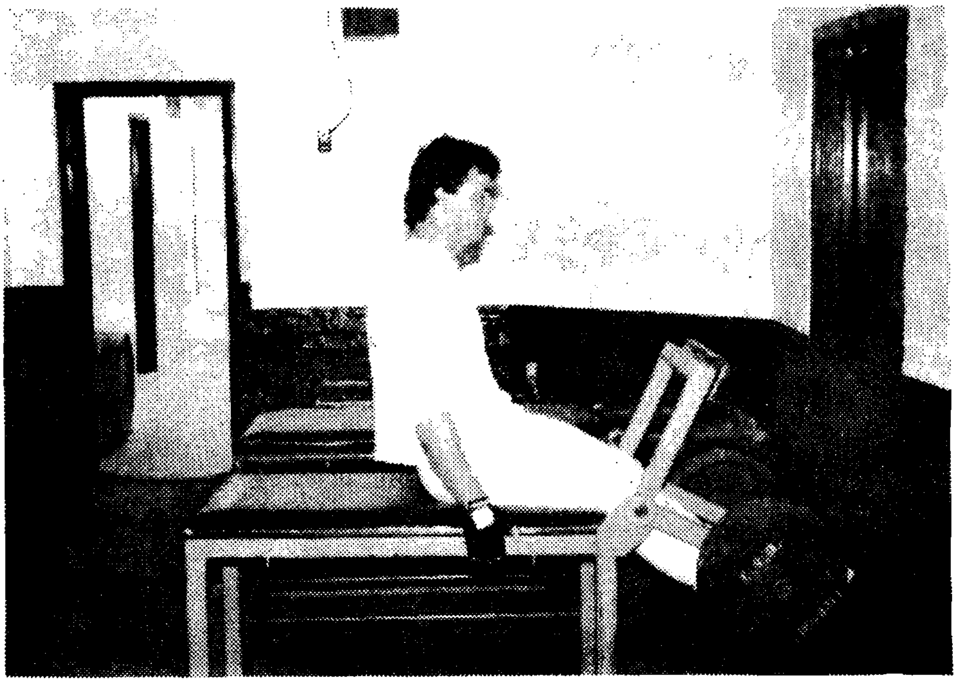


In the E.S.U. program, the squat is done by starting out in a standing position, feet parallel with the toes angling out, shoulder width apart. The subject keeps his feet stationary and slowly "squats" to a position shown above, with heels down, eyes up and tops of thighs parallel to the ground.

Appendix K

The Leg Extension Exercise

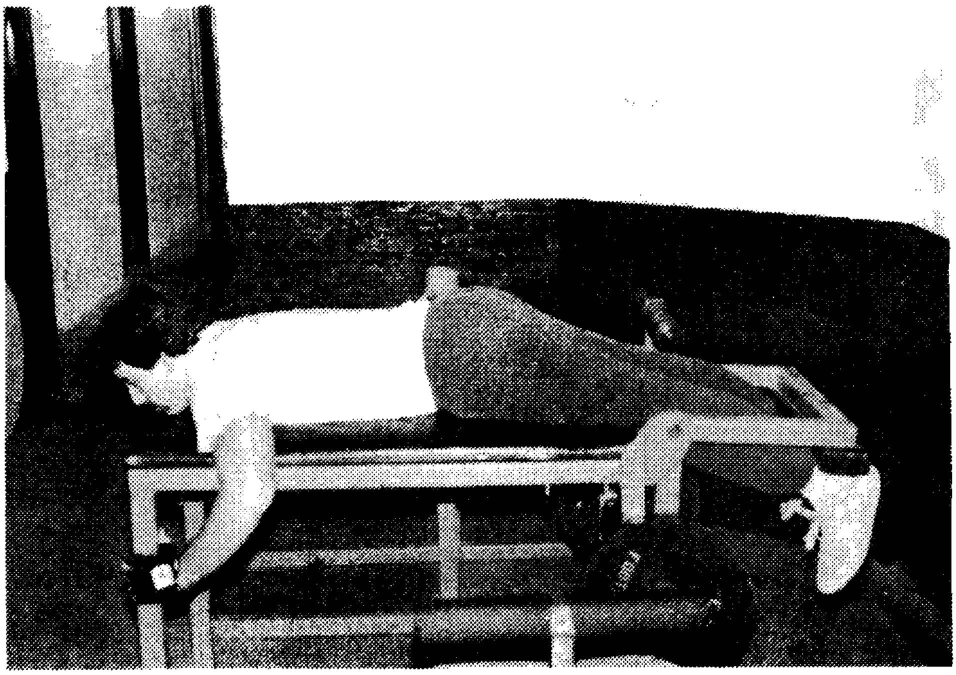


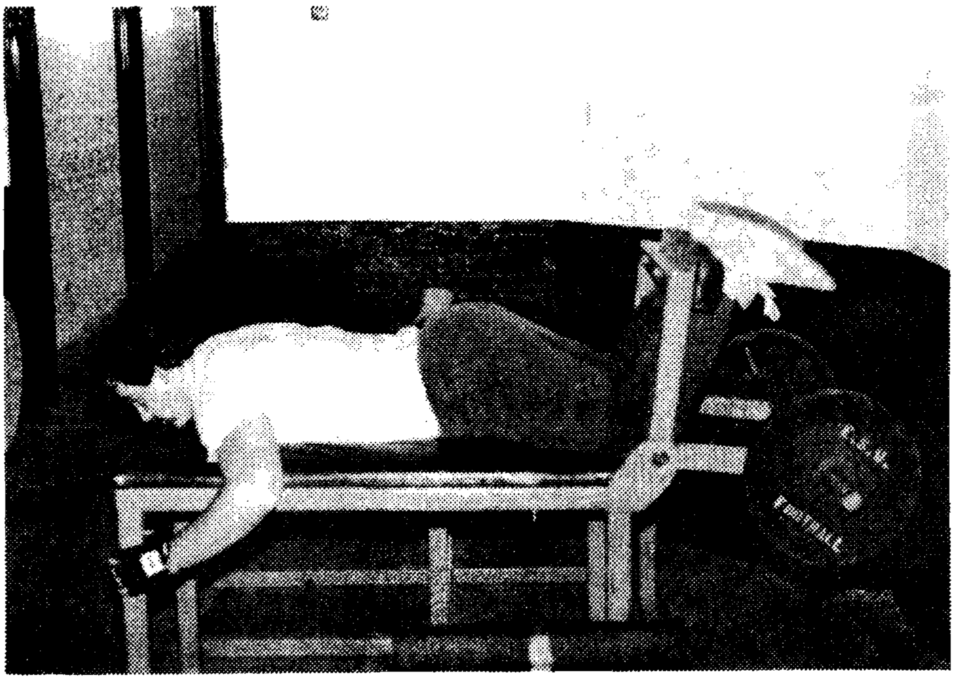


In the leg extension exercise the subject begins with the weight down. He contracts the quadricep muscle group forcing the leg to lock straight. He continues these reps throughout the set.

Appendix L

Hamstring Curl Exercise

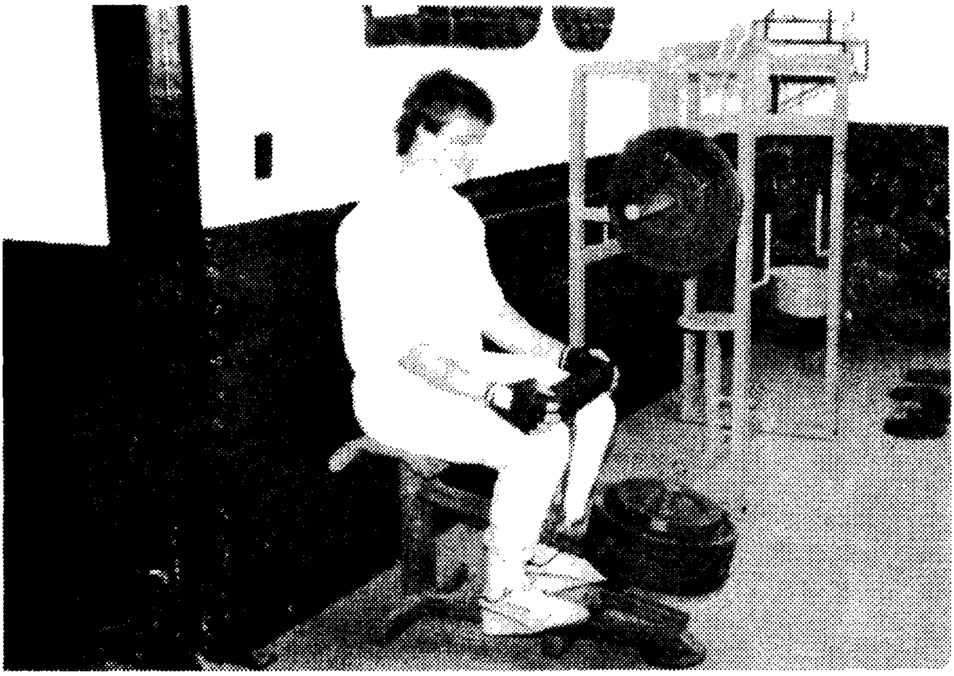


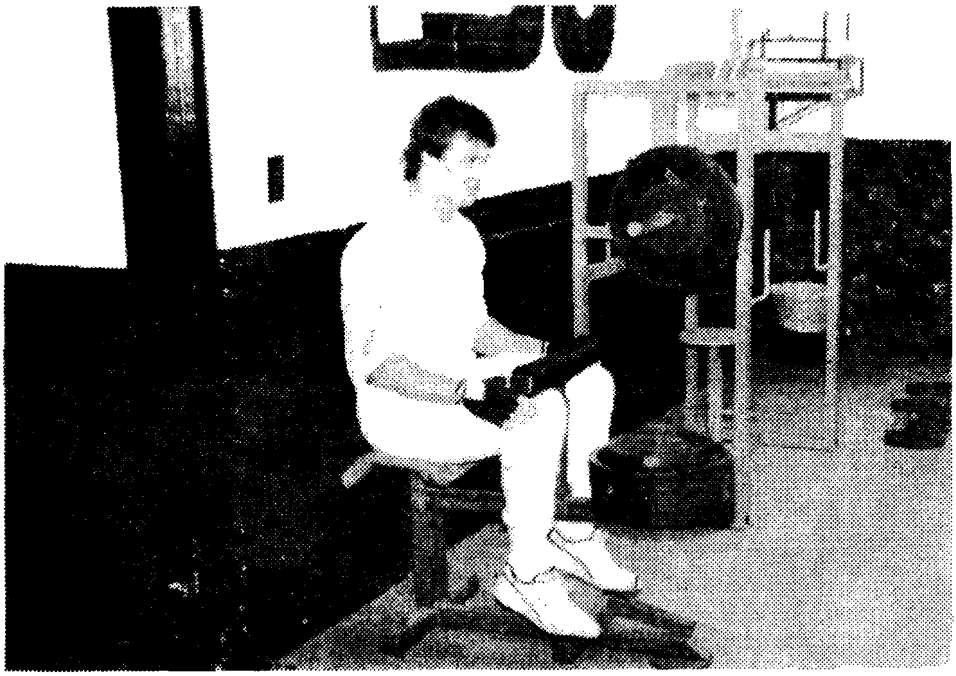


The leg curl exercise begins with the subject at rest. He then pulls both heels up to his buttocks as rapidly as possible. He continues this action throughout the set.

Appendix M

The Heel Raise Exercise

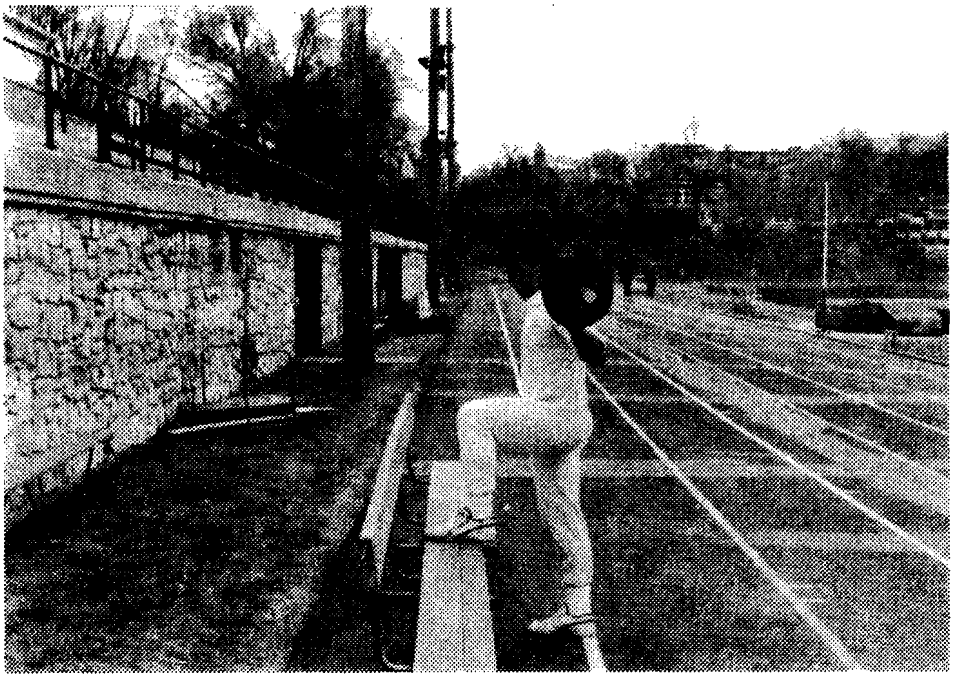


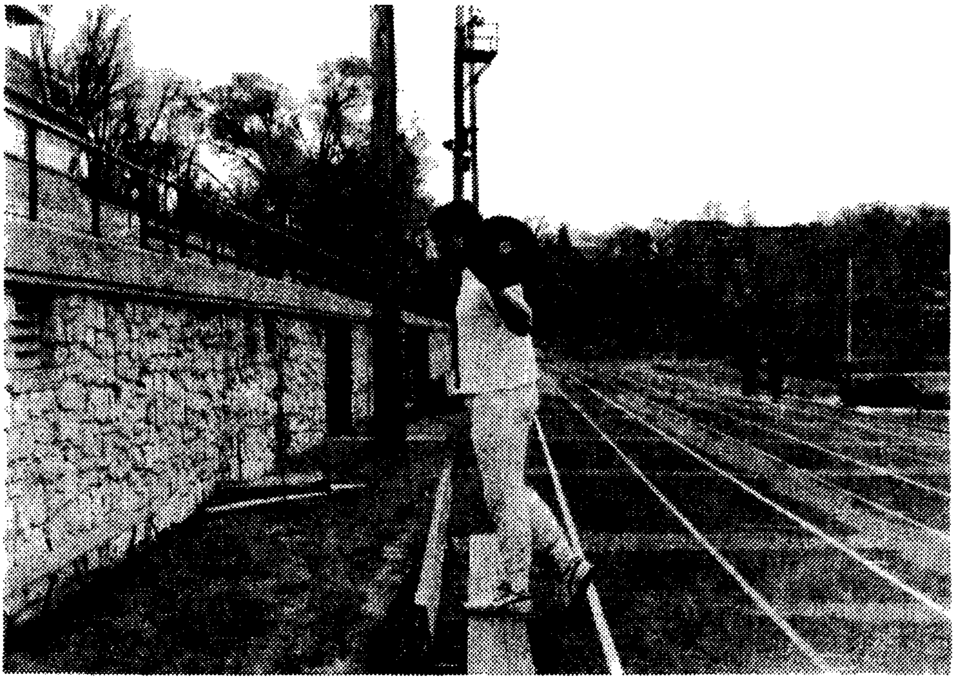


In the heel raise exercise the subject begins with his heels down and simply flexes his calf muscle, bringing his heels up as far as he can. He continues this action throughout the duration of the set.

Appendix N

The Step-up Exercise

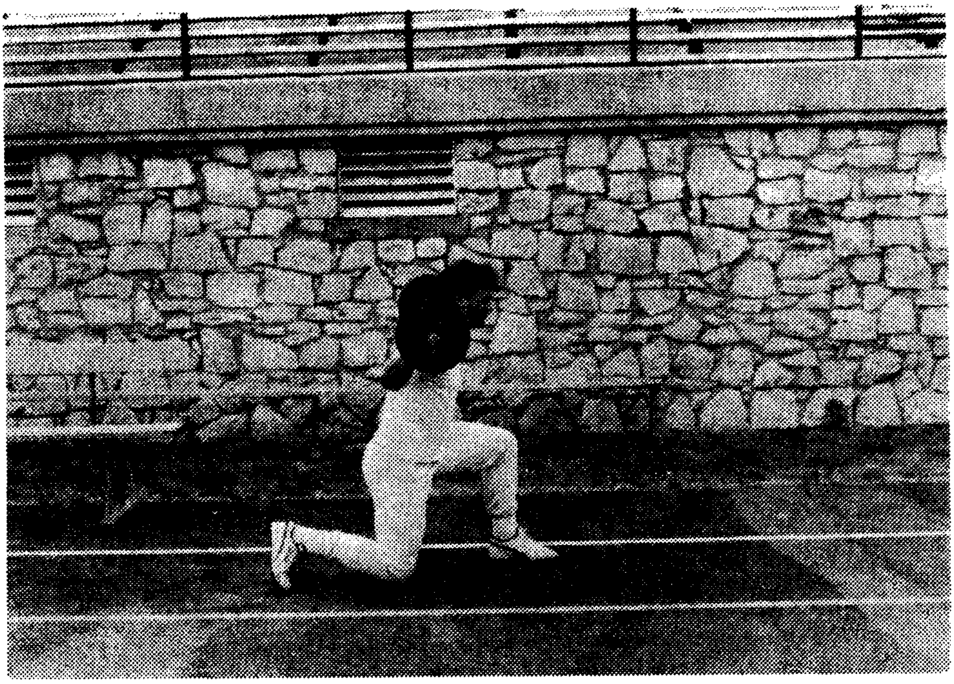


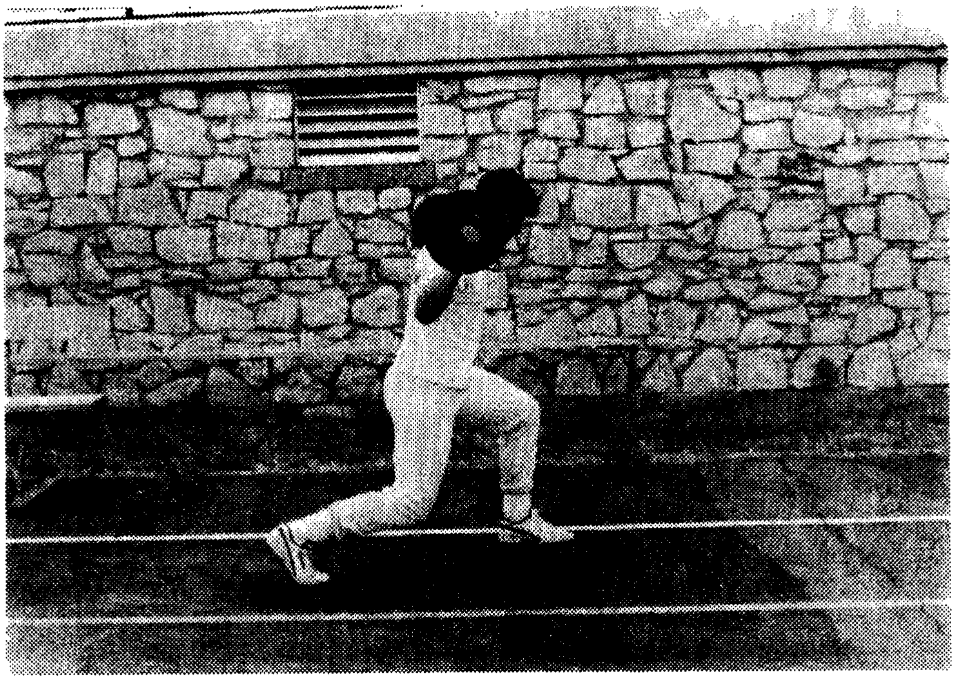


The step-up exercise begins with the subject placing his foot on the bench. He then simply "steps up" so that his leg is extended and his opposite foot remains off the bench. He continues this same action with the same leg throughout the duration of the set. Emphasis is also placed on coming down in a "controlled: manner.

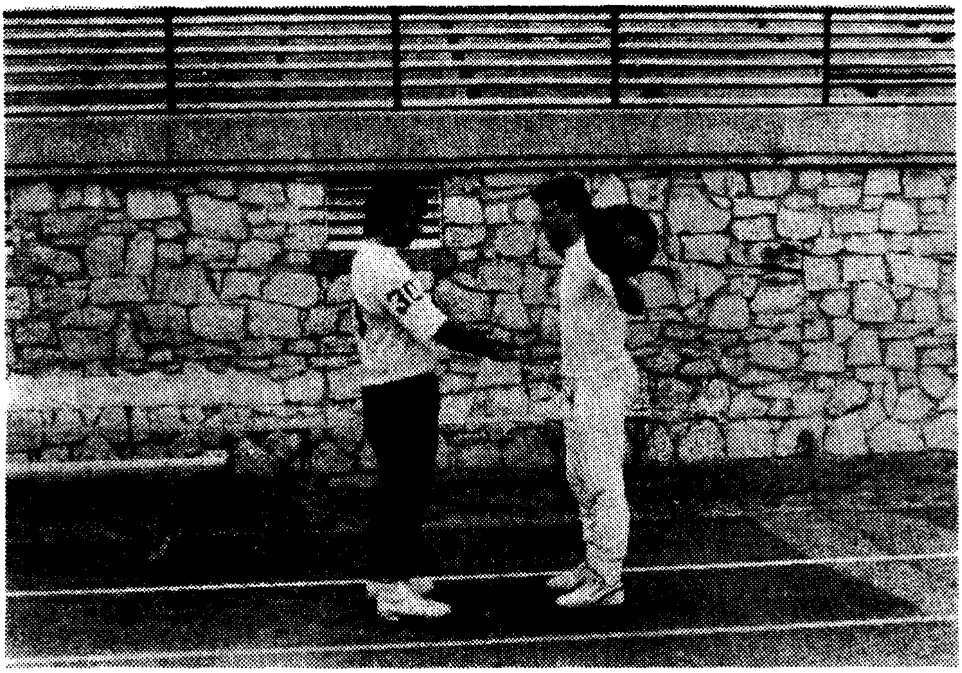
Appendix O

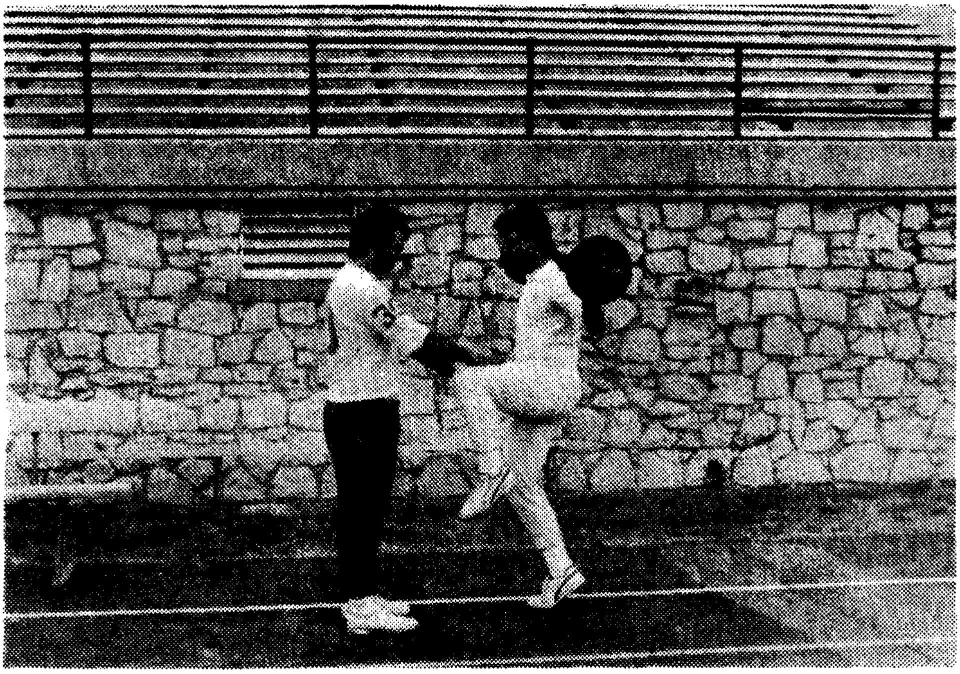
The Lunge Exercise





The lunge begins with the subject standing. He then "steps out" to a position (bottom figure) where the top of his thigh and shin are at a 90° angle. He then comes directly up to resume the standing position. This action is repeated using the same leg throughout the duration of the set.





The Stationary running exercise begins with the partner standing with his hands at navel height. The subject then runs in place as rapidly as possible on his toes making sure his knees hit his partner's hands on every exchange.

Appendix Q

Data Recording Sheet

DATA RECORDING SHEET

CODE NUMBER: ________ GROUP: _________ DATE: _________ TIME: _______

WEIGHT: ________ lbs. = ________kg

HIPSLED MAX: _______lbs.

40 YD. DASH: TRIAL 1: _______SEC TRIAL 2: _______SEC. TRIAL 3: _____SEC.

POWER TEST: TRIAL 1: _______SEC. TRIAL 2: _______SEC. TRIAL 3: _____SEC.

W = _______ kg

D = _______ meters

t = _______ sec. (Best time of 3 trials)

P = ___x___

P = _______ kg-meters per sec.

Appendix E

The Margaria-Kalamen Power Test