THE EFFECTS OF ISOMETRIC AND ECCENTRIC STRENGTH TRAINING PROGRAMS ON ISOMETRIC LEG STRENGTH

by

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ABSTRACT

The purpose of this study was to compare the effects of strength training by eccentric and isometric contractions in relation to isometric right leg strength. A secondary purpose was to determine if individual differences in eccentric strength gains were related to individual differences in isometric strength gains.

Forty-five volunteer subjects were systematically assigned to three groups in such a manner that these groups were balanced in terms of initial isometric leg strength. The groups were then randomly assigned to experimental and control conditions. One group trained with eccentric contractions, another with isometric contractions and the last acted as a control. The groups were tested for isometric leg strength before and after a six week training program. The Eccentric Group was also tested for eccentric leg strength during the first and last training sessions. The training sessions took place three times per week and three maximal contractions were performed during each session.

The results indicated that both isometric and eccentric training produced significant isometric strength gains \( t = 7.13, 6.64 \) respectively, \( p < .05 \) when compared to the Control Group. However, there was no significant difference between the strength gains of the two experimental groups \( t = .49, p > .05 \). Within the eccentrically trained group
it was also found that eccentric strength was significantly improved due to training ($t = 5.52, p < .05$) but that this improvement was uncorrelated ($r = .27$) with isometric improvement scores.

Within the limitations of this study, it was concluded that isometric and eccentric training were of approximately equal value in increasing isometric strength. Further, there was no relationship between isometric improvement scores and eccentric improvement scores.
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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

Finding the best method of improving muscular strength has long been a problem among physical educators. There have been many opinions as to which method is best for strength development with early emphasis on the isotonic type of exercise using concentric muscle contractions. De Lorme (1) used progressive resistance training, which is a type of isotonic training, to improve strength. Von Gertten as reviewed by Josenhans (2:315) used isotonic contractions to develop muscle strength and considered muscle tension the effective factor in developing strength. In 1953, Hettinger and Muller (3) published a paper showing the value of static-type or isometric contractions.

Many recent studies have been concerned with comparing isotonic and isometric training programs in an effort to determine which method would result in superior strength development. The results of these studies have been varied and not compatible. Several studies (4,5,6,7,8) have compared isotonic and isometric training and shown that there was no significant difference between the two methods in increasing strength. Other studies have shown significant differences in rate of strength improvement between the two
types of training. Liberson and Asa (9) and Mathews and Kruse (10) concluded that static training was more effective and Meadows (11) and Rasch and Morehouse (12) showed that isotonic training was more effective for increasing strength.

For a few years, the general opinion was that these two methods (isotonic and isometric) were the only feasible ways in which strength could be developed. However, Banister (13) has recently experimented with a variation of the isotonic method involving forced eccentric contractions. The use of eccentric contractions was based on the fact, as had been shown by Doss and Karpovich (14), that a muscle will develop a higher tension during an eccentric contraction than during an isometric or concentric contraction. Many researchers including Clarke and Clarke (15:165), Hettinger (16:75) and Banister (13:1) maintained that the amount of muscle tension used in training was of prime importance for the gain in muscular strength. Because muscular tension has been considered so important in strength development, it follows that the training program which develops the most muscular tension should be the best method of strength development.

The Problem

The purpose of this study was to compare the effects of a specific isometric leg strength training program to a specific eccentric leg strength training program in relation to improvements in isometric leg strength.
Subsidiary Problem

A secondary problem was to determine the relationship between individual differences in isometric leg strength improvements and individual differences in eccentric leg strength improvements of an eccentrically strength trained group.

Need for the Study

Strength has often been considered a basic component of physical fitness. Improvements in strength have usually been associated with improvements in fitness as well as with improvements in specific motor skills. The question has arisen, "What is the best way to develop strength?" Many studies have compared isometric and isotonic programs. Very little experimentation has been done with eccentric training programs, and their value when compared to the proven methods of strength development.

Limitations

The results and conclusions drawn from this study were limited by several factors:

1. The forty-five volunteer subjects were drawn from the Physical Education and Recreation Department of the University of British Columbia.
2. No restrictions were placed on sleep, diet and recreational activities although the subjects were restricted from participating in interscholastic sports and weight training.

3. Strength training required an effort on the part of the subjects and therefore was influenced by motivation.

4. The study was composed of a six-week, three times per week training program.

5. An isometric test was used to measure strength increases.

Delimitations

The scope of the study was concerned only with the effects of a specific isometric and specific eccentric training program upon isometric and eccentric leg strength.

Null Hypotheses

1) $H_0: \mu_1 = \mu_2 = \mu_3$

$H_1: \mu_1 \neq \mu_2 \neq \mu_3$

where $\mu_1 =$ mean isometric strength due to an isometric training program

$\mu_2 =$ mean isometric strength due to an eccentric training program

$\mu_3 =$ mean isometric strength of a control group.

2) $H_0: \rho = 0$

$H_1: \rho \neq 0$
where \( p \) = the correlation coefficient between mean isometric strength and mean eccentric strength due to an eccentric training program.

Definitions

1) **Isometric muscle contraction.** A muscular contraction in which the muscle fibers are stimulated to contract but not allowed to shorten to any meaningful extent.

2) **Isotonic muscle contraction.** A muscular contraction in which the muscle fibers are able to either move the load or the load is great enough to overcome the fibers and stretch them, even though the muscle is continually stimulated to contract. The former type of contraction is called a **concentric contraction** and the latter type is called an **eccentric contraction.**
REFERENCES


CHAPTER II

REVIEW OF THE LITERATURE

The related literature has been classified into five areas:

1) Isometric Strength Training
2) Eccentric Strength Training
3) Muscle Tension and Strength Development
4) Measuring Leg Strength
5) Specificity of Strength Improvement

Isometric Strength Training

There has been a great deal of research done in the area of isometrics and their influence on strength. This section has been divided into three areas:

1) Isometrics
2) Isometrics versus Isotonics
3) Length and Force of Isometric Training

Isometrics. In 1946, Hellebrandt as reported by Rasch (1:46), challenged the assumptions underlying isotonic training techniques, and suggested that in theory more strength might be gained by the use of isometric contractions, since a

... muscle develops maximum tension when the load is so heavy that it is not allowed to shorten at all. Under these conditions the muscle maintains its optimum length for maximum energy production throughout the period of exertion.
Duvall, et al. (2), Darcus (3), and Salter and Darcus (4), disagreed with Hellebrandt and failed to demonstrate any significant improvement in muscular strength from the practice of isometric training.

In 1953, Hettinger and Muller (5) published a study dealing with the value of isometric training. Over an eighteen month period, nine male subjects participated in seventy-one separate experiments, in which training took the form of pulling and holding a pre-determined amount of tension against a spring scale by contracting the flexors and extensors of the forearm. Training occurred Monday through Friday and on each Saturday a maximal isometric strength recording was made. They concluded that isometric training can greatly increase muscular strength measured isometrically.

Steinhaus (6) reported that Hettinger and Muller (5) felt the cause of the increase in isometric strength due to isometric training was neither the intensity of the contraction nor the degree of exhaustion of a muscle fiber, but rather a condition in which the oxygen supply to a muscle fiber ceases to be enough for its needs.

The findings of Hettinger and Muller (5) were lauded by McCloy (7:3) as having "... tremendous significance for the entire field of physical conditioning."

Liberson and Asa (8) studied brief isometric exercises and found Hettinger and Muller's (5) conclusions to be premature. They pointed out that the strength of a muscle is
at a maximum when the muscle is induced to contract at its normal resting length. During isotonic contractions, the muscle approaches its normal resting length only intermittently and for very brief periods of time, whereas during an isometric contraction it may be contracted at its optimal length during the entire exercise period. They found that while a continued isometric strain may result in obstruction of the blood flow, intermittent isometric strains perhaps serve as blood pumps. This explained why they found repeated isometric exercises more effective than a single bout of exercise in spite of Hettinger and Muller's assertions to the contrary.

Kroll (9) gave thirty male subjects twenty trials of isometric wrist flexion on each arm. The trials consisted of five seconds of maximal exertion followed by thirty seconds' rest. Analysis of variance of fatigue curve trends suggested that there was no biologically fixed and constant intensity level of isometric muscular tension which occluded intramuscular circulation.

Banister (10:2) described static training as that in which

... the load is large enough to prevent shortening even with all the muscle fibers activated synchronously (tetanic stimulation). High intramuscular tensions can be exerted with total innervation (excitation) of all the muscle fibers and a good training effect produced.
Isometrics versus Isotonics. Lorback (11) found that static six second contractions at two-thirds maximum strength three times a week for eight weeks provided significant increases in isometric strength. He also found no significant differences between such increases and those obtained by a similar progressive resistance exercise program.

Baer, et al. (12), divided sixty-three subjects into six groups:

1) High resistance isotonic exercises, 10 contractions/min. for four weeks.
2) High resistance isotonic exercises, 30 contractions/min. for four weeks.
3) Low resistance complex motion exercises, 10 contractions/min. for six weeks.
4) Very high resistance isotonic exercises, 10 contractions/min. for four weeks.
5) High resistance isometric exercises, 10 contractions/min. for six weeks.
6) Medium resistance isotonic exercises, 10 contractions/min. for six weeks.

Each group exercised right upper extremities one period a day five times a week. There were no significant differences among isometric strength improvements produced by different training programs, although the greatest improvements resulted from high resistance isotonic training.
Salter (13) divided her subjects into groups of four. Each group was trained in supination of the left hand by one of the following systems:

1) Isometrically at the rate of fifteen contractions per minute.
2) Isometrically at the rate of two contractions per minute.
3) Isotonically at the rate of fifteen contractions per minute.
4) Isotonically at the rate of two contractions per minute.

The results showed no significant difference between the four methods of training in their effect on isometric strength.

Darcus and Salter (14) studied the effects of daily training sessions which consisted of either thirty isometric or thirty isotonic contractions at intervals of one minute. They concluded that (14:336):

Both types of training resulted in an increase in the strength measured both isotonically or isometrically, although the effects of static training were not immediately apparent.

Rasch and Morehouse (15) found that in elbow flexion exercises (three isometric elbow flexions for fifteen seconds each at two-thirds maximum strength with three minutes rest between) there was no significant increase in isometric strength. In arm elevation exercises with conditions the same as in the elbow flexion exercises, the isometric group showed
a significant mean increase in isometric strength. Subjects who performed isotonic exercises showed a significantly greater gain in isometric strength and hypertrophy than did subjects who trained isometrically.

Wallace (16) divided thirty-three college women into three groups (isometric training, isotonic training, control). The subjects were tested before and after a four-week training program and the results showed no significant differences between groups in the improvements of elbow flexion strength.

Petersen (17) compared muscle training by static, concentric and eccentric contractions. Twenty-four adult females and twenty-three adult males participated in the experiment. Seventeen females and seventeen males underwent a training period of from twenty to thirty-six days. Their training consisted of one of the following forms of exercise: one daily maximum isometric contraction, ten daily maximum isometric contractions, ten daily eccentric muscle contractions or fifteen minutes of daily heavy dynamic work (riding a bicycle ergometer). The effects on the isometric strength of the trained groups was compared to a control group of seven females and six males. The results showed that one daily maximum isometric contraction had no effect on the isometric strength of muscles, ten daily maximum isometric contractions increased the isometric strength of muscles, and heavy dynamic work increased isometric strength in both males and females. The control group showed no significant change.
Berger (18) trained fifty-seven male college students three times a week for twelve weeks with static contractions. One hundred and seventy-seven students were also trained for the same length of time with dynamic contractions which varied in bouts and repetitions. The results showed that training statically for six to eight seconds at two different positions was more effective in increasing isometric strength than training dynamically with two repetitions for one to two bouts but not as effective as training dynamically with three bouts of six repetitions.

Chui (19) studied the effects of isometric and dynamic training exercises upon the strength and speed of execution of single movements. Seventy-two male subjects were assigned to one of three experimental groups (isometric, rapid dynamic, slow dynamic). A control group was composed of twenty-four male subjects. Eight strength scores for each subject were taken with a cable tensiometer. The results showed that gains made by the isometric group were not significantly greater than gains made by the isotonic group and that gains made by the rapid dynamic method were significantly greater than gains made by the slow dynamic group.

Belka (20) trained four equated groups of five subjects using static, dynamic, combination static-dynamic, and control procedures to compare effects on strength of the flexors of the dominant wrist. The static and dynamic groups each performed six bouts of three repetitions daily for five weeks.
The combination group completed three bouts each of dynamic and static training. Maximum dynamic and static strengths at three angles were recorded before and after training. No significant differences were found among experimental groups in developing static strength of the dominant wrist flexors. Compared with the control groups, all experimental groups improved significantly in one or more specific strength test.

**Length and Force of Isometric Training.** Steinhaus (6) summarized Hettinger and Muller's (5) findings:

1) Muscle strength increases an average of five percent per week when the training load is as little as one-third or even less of maximal strength.

2) Muscle strength increases more rapidly as the intensity of the training load goes up to about two-thirds of maximal strength. Beyond this, increased intensity of training load has no effect.

3) One practice period per day in which tension was held for six seconds resulted in as much of an increase in strength as longer and more frequent periods.

According to Howell (21) many of the early findings dealing with isometric training were modified by Muller (22,23) and Hettinger (24). He reviewed Hettinger's (24) findings:
1) The maximum training effect possible was achieved by using only forty to fifty percent of the maximum strength in voluntary isometric contraction.

2) No change in strength was observed when only twenty to thirty percent of muscle strength was used.

3) Gradual losses in muscle strength were observed when less than twenty percent of muscle strength was used.

4) Maintaining a maximum isometric contraction for only one to two seconds is sufficient to provide a training stimulus. When the contraction involves only two-thirds of maximum strength, the contraction should be maintained for approximately four to six seconds.

5) The maximum increase in muscle strength was obtained with one training stimulus per day.

6) Several repeated maximum contractions are no better for strength increase than only one.

7) When training sessions were held only each second day, the increase in strength was eighty percent of strength gained through once a day training.

8) The average in strength increases per week was found to be 1.79 percent with a standard deviation of 1.2 percent.
Taylor (25) compared four isometric training programs; a maximum pull for twelve seconds, a maximum pull for six seconds, a two-thirds maximum pull for twelve seconds, and a two-thirds maximum pull for six seconds. He found that:

1) No one of the four methods was significantly better for increasing the contractile strength of the muscles involved in right wrist dorsal-flexion.

2) The training method of two-thirds maximum pull for six seconds was significantly better at the five percent level than the two-thirds maximum pull for twelve seconds in increasing the contractile strength of muscles involved in right hip outward rotation.

3) All of the training methods except the two-thirds maximum pull for twelve seconds produced significant improvement in the contractile strength of right wrist dorsal flexion when compared with the same strength of a control group.

4) Two methods, maximum pull for twelve seconds and two-thirds maximum pull for six seconds, produced significant improvement in right hand outward rotation contractile strength when compared with a control group.
5) The difference in favor of the experimental group over the control group was not always significant but in every case there was a higher group mean for the experimental group than for the control group.

Asa (26) found that a repetitive isometric group doing twenty, six second contractions daily, four days a week for twelve weeks, gained a significantly higher degree of isometric strength than a single isometric group doing one, six second contraction a day, four days a week, for twelve weeks. However, all subjects in both groups showed significant increases in isometric strength.

Wolbers and Sills (27) measured twenty male subjects for strength with four isometric tests before and after an eight week training period. Ten of the subjects were subjected to static exercises once a day for six seconds each. The subjects met daily and trained under motivation. The experimental group made significantly greater gains in back life strength, leg lift strength, and combined grip strength than the control group. It was concluded that for the muscle groups tested, static contractions of six second duration will increase isometric strength significantly.

Lorback (11) as mentioned previously, found that static six second contractions at two-thirds maximum strength, three times a week for eight weeks provided significant increases in isometric strength.
Liberson and Asa (28) studied two programs, a single daily isometric contraction held for six seconds and a twenty times daily contraction held for six seconds. Repetitive contractions were found to be more efficient than single contractions for isometric strength improvement.

Walters, et al. (29) compared two isometric programs, isometric exercises with maximal resistance and isometric exercises with two-thirds maximal resistance. Both methods were effective in increasing isometric strength, with the maximum resistance method the better of the two.

Rarick and Larsen (30) tested the effectiveness of a single six second isometric contraction at two-thirds maximal tension with higher levels of isometric tension held for progressively longer time periods each day in developing static muscular strength of boys. Results showed the strength of the experimental groups were significantly higher than the control group after training. The data also indicated that tension levels greater than two-thirds maximum with more frequent exercise bouts were not superior to the single, daily, six second bout in building isometric strength.

Meadows (31) trained subjects isometrically three days a week for ten weeks and found significant improvement at the one percent level in the speed of the offensive football charge, the force of the charge, and in chins, dips, vertical jumps and back lift.
Perkins and Kaiser (32) studied the effects of a six second maximal isometric exercise on three muscle groups. Twenty subjects with an average age of 73.6, performed the training three times weekly. The results showed a gain of approximately fifty percent in resistance at the time of plateau.

Adamson (33) administered a four week isometric training program involving six maximum pulls at ten second intervals using dynamometers adapted for elbow flexion and spine extension. The subjects showed a significant increase in isometric strength following the training program.

Mathews and Kruse (34) analyzed the results of a training program involving three consecutive six second maximal isometric contractions. Sixty subjects were divided into four groups which trained two, three, four, and five times per week. Forty-four of the sixty subjects made significant isometric strength gains with the five times per week program being the most beneficial.

Mayberry (35) studied the effects of maximal and fifty percent of maximal static contractions performed once daily for five weeks by the muscles of one extremity on the strength of the exercised and related muscles of that extremity and the symmetric and related muscles of the opposite unexercised extremity. The analysis of results indicated no significant isometric strength improvement of the exercised or non-exercised wrist flexors. Mayberry indicated that a single
static contraction of a muscle done once a day is not a sufficient amount of exercise to result in an increase in the isometric strength of the exercised muscle.

Howell and Shaw (36) examined the findings of Petersen (17). Two groups of nineteen boys were placed into equivalent groups on the basis of isometric strength scores on a tensiometer with grip attachment. The experimental group performed one maximum isometric contraction of the right forearm flexors daily for six seconds over a four week period. A dynamometer was used by the exercised and unexercised limbs of both groups once weekly. Results showed that there were statistically significant increases in isometric strength at the one percent level in the exercised and unexercised arms of the experimental group at the end of four weeks. Each group was tested at the end of each week of training and results showed that there were statistically significant differences in isometric strength between the groups in favor of the experimental group at the end of the first, third and fourth weeks.

Because of the inconsistency of results of studies on isometric contractions, Muller and Rohmert (37) investigated the relationship between workload and duration of contractions and isometric strength increase in static training. Five types of training were administered; four with maximum static contractions as load but varying in duration and frequency
per day (one second—one per day, four seconds—ten per day, six seconds—five per day, one second—one per week) and one involving sixty-seven percent of maximum force (five to forty-five seconds—one per day). The progress of the subjects was plotted and the rate of increase per week became smaller as the subjects approached their maximal strength level. The following conclusions were summarized from the above mentioned results:

1) The larger the ratio between static load and initial maximal force, the greater the rate of increase in strength.

2) The smaller the ratio between the initial maximal force and the (estimated) maximum strength level, the greater is the rate of increase in strength.

3) The maximum strength level and rate of strength increase become larger when the duration of the maximal static contraction is changed from one to five seconds.

4) Contractions below a certain force level have no training effect.

5) Repeating a short maximal contraction several times a day does not increase the training effect.

6) A single maximal training contraction acts as a gradually diminishing stimulus for strength increase for a period of seven days.
McGlynn (38) divided sixty subjects into two equal groups, control and experimental. Each group was tested before and after a twenty day training period with a strain gauge. The experimental group was also tested every five days. Training for the experimental group consisted of holding two minute isometric contractions twice a day. It was concluded that a two minute maximal isometric exercise repeated twice a day for a period of five days will lead to a large gain in initial isometric strength. Isometric training continued after five days produced no significant gains in initial isometric strength. Isometric training continued after fifteen days resulted in significant decreases in initial isometric strength.

Banister (10:2) said of isometric training:

Recommendation of one-third, one-half, or two-thirds maximum effort as the best training stimulus seems theoretically to have little basis since, in order to realize full strength potential, total innervation of all motor units at the maximum fiber tension should be practised.

**Eccentric Strength Training**

The first published study on eccentric training was completed by Petersen (17) whose methodology and results have been reported in the previous section. Although Petersen did not produce significant strength gains with an eccentric training program, he did say of eccentric contractions (17:409):
The maximum tension registered during this form of contraction was about twenty to thirty percent higher than that developed during the training by maximum isometric contractions.

Banister (1) trained seven Olympic and European rowers during a three month, three times a week training schedule on an eccentric ergometer. They combined both eccentric and concentric training and at the end of the three months had all made significant eccentric strength increases.

Banister (39:8) said of eccentric contractions:

Individual muscle fibers are made to obtain more of their full contractile potential and, although fewer fibers need to be innervated to achieve the equivalent amount of work as is done in a concentric movement, it only remains to increase this work load drastically to include all the fibers once more.

Merton (40:557) stated:

... cases where athletes and others snap their tendons or knee caps are probably to be explained by the forces, considerably in excess of the normal maximal tetanic tension, that muscles can be subjected to if they are stretched during a contraction.

Hill and Howarth (41:170) found that:

... contracting muscles resist an applied stretch very strongly, with a force which may be twice that of a maximal isometric force.

Asmussen (42) found that when a muscle fiber which was in a state of isometric contraction was allowed to contract during continuous stimulation, the isotonic strength curve was well below the isometric strength curve. On the other hand, when this fiber was lengthened forceably, the tension curve was well above the isometric curve.
Doss and Karpovich (43) made a study of the concentric, eccentric, and isometric strength of elbow flexors. Thirty-seven physical education students from Springfield College were tested three times on each of three tests to measure force in concentric, isometric and eccentric contractions. The results showed that eccentric contractions of the same muscle produced 13.5 percent greater force than isometric contractions and concentric contractions produced a force twenty-three percent smaller than isometric contractions.

Muscle Tension and Strength Development

Clarke and Clarke (44:165) found that:

Hypotheses have been supported that the amount of tension developed in a muscle is a major factor in determining strength improvement and that the work done per unit of time is the factor essential in the extension of muscular strength and muscular endurance performances.

Griffin (45) theorized that increasing the amount of tension produced within a muscle for a certain period and sometimes over a certain range of motion was the basis for the overload system which is used in all strength development programs.

Rasch and Morehouse (15:33) explained strength improvement in unexercised limbs by stating:

Observations of the subjects during the training period suggested that with both isotonic and isometric exercise there tended to be more or less tension in the contralateral arm during
unilateral exercise, such tension appearing to increase as the exercise became more difficult for them. In effect, this may be considered a form of isometric exercise which possibly was responsible for the slight increases in hypertrophy in the contralateral arm.

Hettinger (24) reviewed many of the early studies on the role of a training stimulus in increasing muscular strength. He agreed that an increase in muscle tension above that previously demanded of a muscle is the stimulus for an increase in muscle strength. In the summary of his book, Hettinger (24:75) stated:

It has been shown that muscle tension, i.e. the training strength, seems to be the important point in muscle training.

Buchtal and Kaiser (46:350) used a myograph to study the mechanical changes taking place with isotonic and isometric contractions. They found:

The conditions under which training takes place determine the degree of increase in muscle substance. . . One must presume that tension is the deciding factor in the growth of the muscle's physiological cross-section.

Banister (39:5) said:

The problem of training muscle strength is to make the muscle able to realize its full potential so that all the fibers are able to be innervated and also contribute their maximum tension.

Wolbers and Sills (27) found that a muscle develops in size and strength only as it is overloaded, that is as it is required to exert force against greater resistance than it normally does.
Muller (47) found that three factors influence maximum strength development: the force of the training contraction, the length of time for which the contraction is held, and the number of contractions per day. Banister (10:1) said of muscular tension:

. . . any review of weight training methods involves the basic premise that the tension generated in the muscle is important as the stress factor in training.

Measuring Leg Strength

In 1938, Carpenter (48) published a study on leg angles and measurement of leg lift. Twenty college students performed leg lifts six times a day for eighteen days, with the knees at six different angles. The lifts were performed according to instructions from Rogers' Physical Capacity Tests. Knee angles were adjusted by varying the attachment of a bar to various chain links. The results showed that at angles from 115 degrees to 124 degrees, the most consistently high scores were attained. Angles of above 139 degrees and of below 115 degrees were definitely inferior.

Everts and Hathaway (49) found the best angle for measuring leg strength was about 130 degrees.

By the use of tensometers on cadaver limbs, Haxton (50:286) found that:

. . . in the knee and elbow joints the leverage of the action of the extensor muscles on the joints becomes greater as the joints are extended from the flexed positions.
He found that between sixty degree and 150 degree positions the improvement in the leverage of the quadriceps was 42.2 percent of the figure at sixty degrees.

Hugh-Jones (51) studied the effects of limb position on the contractile force of muscles. Maximum leg push results were recorded for six male subjects. A foot pedal was placed in front of a seat and on the same plane as the hip-joint of the experimental subject in the seat. The pedal was mounted in different positions for each of five different knee angles and the relationships between push and knee angle was found. Each subject recorded at least three maximum efforts of each angle and the mean of the two similar readings was taken. The mean pushes of the subjects showed no significant differences between legs and therefore only the measures of the right legs were used in the tables. The mean push exerted on the isometric pedal was found to rise sharply as the knee angle increased to 160 degrees and then dropped sharply as the angle of the knee went beyond 160 degrees.

Clarke (52) studied the results of twenty-eight cable-tension strength tests administered separately by two investigators to sixty-four students chosen at random. A product-moment coefficient of correlation was computed between the scores obtained by the two testers. The resulting correlations were called objectivity coefficients. The co-
efficient for knee extension was .94. The accepted standard indicating desirable objectivity was found to be .90.

McCloy (53) recommended the use of a knee-angle of 120 degrees when performing leg-lifts with a dynamometer. He also stated that it is best to rest the bar on the bare skin of the upper thigh or upon a pad of soft cloth on the upper thigh.

Horitz et al. (54) used a specially constructed muscle dynamometer to study the effect of posture on the strength of knee flexion and extension of eight females between the ages of twenty-three and fifty years of age. Three maximal effort tests in seven positions through a range of knee motion, were performed by females in the sitting, supine and prone positions. In the sitting position the subjects were instructed to grasp the edge of the table and a pad was put under the distal end of the thigh to afford padding. The mean of the three maximal contractions was used as the score at each of seven positions varying in fifteen degree increments from 75 degrees to 165 degrees. The top strength score in pounds was recorded at a knee angle of 135 degrees.

Clarke (55:142) described the development of the cable-tension strength tests when he stated:

More recently, Clarke adapted the tensiometer, an instrument designed to measure the tension of aircraft control cable, for testing the strength of individual muscle groups. Cable tension is determined from the force needed to
create offset on a riser in a cable stretched between two set points, or sectors. This tension can be converted into pounds on a calibration chart.

Kennedy (56) investigated the possibility of substituting the relatively inexpensive cable tensiometer for the back and leg dynamometer in the Rogers Physical Fitness Index Test. The tensiometer was calibrated against the criterion of the dynamometer. College men performed with both instruments on a test-retest pattern to determine by correlation means if the two tests were in agreement. The correlations between strength scores obtained with the dynamometer and tensiometer were .92 and .95 for the back and leg lifts respectively.

Clarke and Clarke (44) reviewed Clarke's Cable Tension Tests for measuring the strength of individual muscle groups. They found Clarke had reported his findings in a series of articles (52, 57, 58, 59). They also described the knee extension strength test (44:92):

starting position (a) subject in sitting, backward leaning position; arms extended to rear, hands grasping sides of table. (b) knee on side tested in 115 degree extension.

attachments (a) regulation strap around leg midway between knee and ankle joints. (b) pulling assembly attached to hook at lower end of table.

precautions (a) prevent lifting buttocks. (b) prevent flexing arms.
Lindeburg (60) tested thirty-seven high school boys for leg strength in an inverted leg press position at various angles of the leg on the thigh, 100°, 110°, 120°, 130°, and 140°, to determine the best angle for optimum muscular efficiency. Reliability coefficients were high. The subjects extended their legs approximately twenty degrees when exerting a maximum contraction. Between the starting angles ranging from 100 degrees to 140 degrees, measured with a protractor between the malleolus bone of the ankle, the head of the tibia on the knee and the middle of the high, there was no significant difference in leg strength at any one of the angles.

Campney and Wehr (61) measured the knee extension strength of forty-two subjects measured at ten degree intervals for nine joint angles (80-160 degrees). Each test was repeated until the strength scores stabilized at each angle. A curvilinear relationship appeared between knee-extension strength and the joint angles. Clarke's directions for cable-tension strength tests were followed explicitly in this study with the exceptions of the varying joint angles. Results showed decreasing strength scores at angles larger than 120 degrees but little change in strength from eighty degrees to 120 degrees.

Meyers and Piscopo (62) made a study comparing cable-tension strength testing to Manuometer Push Apparatus. Twelve senior men were used as subjects and were tested for push up strength once a day at one week intervals for three
weeks. They performed three trials with cable-tension tests and three with a manuometer push apparatus. The arithmetic mean of the three trials constituted the test score. Results indicated that the cable tension method is the more reliable means of measuring push strength.

Linford and Rarick (63) used a leg dynomometer to measure the leg strength of twenty male subjects at five different knee angles: 115°-124°, 125°-134°, 135°-144°, 145°-154°, 155°-164°. The angular position of the knee was measured with a goniometer. Application of an analysis of variance design and a Scheffe multiple comparison test revealed no significant differences in performance at the one percent level when knee angles were between 135-164 degrees. Knee angles between 115-134 degrees gave significantly lower leg strength scores at the one percent level.

Specificity of Strength Improvement

Many studies (11, 13, 15, 34) have used static strength tests to measure changes due to both dynamic and static training. Berger (64:329) felt that dynamic and static strengths were different and, "... the assumption that an increase in dynamic strength guarantees a proportionate increase in static strength has not been substantiated." He tested seventy-eight male university students both statically and dynamically before and after a twelve week training pro-
gram. The subjects were split into two groups, one training with three maximum six second isometric contractions and the other with eight to twelve consecutive isotonic repetitions with maximum muscular effort. Both groups trained three times weekly, Monday, Wednesday and Friday. The results showed that both groups increased significantly in both strengths with the static group increasing more in static strength and the dynamic group increasing more in dynamic strength. Correlation coefficients between the increment in static strength and the increment in dynamic strength from initial to final testing in each group showed no significant relationships. The coefficients were 0.178 for the statically trained group and -0.089 for the dynamically trained group. The correlation between actual static and dynamic strength was .622 which was significant. Berger concluded that there was no relationship between improvement in static and dynamic strength.
REFERENCES


CHAPTER III

METHODS AND PROCEDURE

Subjects

Forty-five volunteer subjects from the Physical Education and Recreation Department of the University of British Columbia with a mean age of 21.8 years, mean weight of 168.2 pounds, and mean height of 70.6 inches were used.

Experimental Design

The forty-five subjects were all pre-tested for isometric leg strength of the right knee extensors. The testing consisted of taking the average of three trials and converting it to pounds of tension. After the pre-training test, the subjects were ranked from one to forty-five according to their isometric strength scores. They were then assigned to three groups in numerical order with the order of the groups rotated by a factor of one after each trio of subjects. This gave three groups of subjects with approximately the same initial mean isometric leg strength. The three groups were then randomly assigned to either experimental or control conditions. Group one acted as a control group and underwent no training. Group two was an experimental group and underwent an eccentric training program consisting of three maximal eccentric contractions of approximately five seconds in length with a one minute rest in between, for six weeks, three times
per week on Monday, Wednesday and Friday. Group three was also an experimental group and underwent an isometric training program following the same training schedule as group two with the exception that each isometric contraction was held for six seconds.

At the end of the training program, all the subjects were again tested for the isometric leg strength of the right knee extensors. The experimental design is summarized in Table 1.

**Apparatus**

**Isometric Strength Testing.** The Clarke-Schopf Cable-Tension Strength Test for knee extension was used to determine isometric leg strength. A Cable Tensiometer, Model T5-6007-118-00, Serial Number 15482, manufactured by the Pacific Scientific Company in Anaheim, California, was used along with a quadriceps table thirty inches high (Figures 1 and 2). A canvas stirrup and adjustable chain connected a one-sixteenth inch cable to the tested leg and to a hook on the lower support of the table. The Cable-Tensiometer was calibrated before both the pre-testing and post-testing sessions at the Mechanical Engineering Department of the University of British Columbia and was found both times to be consistent with the calibration table provided by the manufacturer.

**Isometric Strength Training.** The Isometric Group trained on a device that allowed very little apparent muscular
TABLE I
EXPERIMENTAL DESIGN

<table>
<thead>
<tr>
<th></th>
<th>Pre-Test</th>
<th>Training Program</th>
<th>Post-Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>1. tensiometer</td>
<td>None</td>
<td>tensiometer</td>
</tr>
<tr>
<td>Group II</td>
<td></td>
<td>1. length 6 weeks</td>
<td></td>
</tr>
<tr>
<td>Specific</td>
<td></td>
<td>2. methods</td>
<td></td>
</tr>
<tr>
<td>Eccentric</td>
<td></td>
<td>3 maximum eccentric contractions 3 times per week</td>
<td></td>
</tr>
<tr>
<td>Training</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group III</td>
<td></td>
<td>1. length 6 weeks</td>
<td></td>
</tr>
<tr>
<td>Specific</td>
<td></td>
<td>2. methods</td>
<td></td>
</tr>
<tr>
<td>Isometric</td>
<td></td>
<td>3-6 second contractions isometrically 3 times per week</td>
<td></td>
</tr>
<tr>
<td>Training</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

shortening during contraction (Figure 3). It consisted of a wooden platform with a hook in the center and a wooden bar also with a hook in its center. A chain connected the two hooks so that the distance between the hooks could be varied by adjusting the number of links between the hooks.

**Eccentric Training and Testing.** The Eccentric Group trained on the Carlin-Banister Exotronic Ergometer, Model 4000, Serial Number 101, manufactured by Exotronic Systems Ltd. in New Westminster, British Columbia (Figure 4). The instrument consisted of an hydraulic piston attached to the center of a metal platform. There was a chain permanently attached to the
top of the piston. The other end of the chain could be attached at any given link, to a metal bar. The metal bar was held in place with a large leather belt strapped around the waist of the subject. Foam rubber was used as padding between the belt and the subject's waist. A push button attached to a control box was used by the subject to activate the piston. A graduated pressure gauge on the control box of the instrument showed pounds of resistance pressure.

Measuring Knee Angle. An adjustable steel goniometer made by the J. Sklar Manufacturing Company in Long Island City, New York, was used to measure all knee angles.

Timing. A Kodak Timer manufactured by the Eastman Kodak Company in Rochester, New York, was used to time rest intervals and training times.

Procedures

Isometric Strength Testing. Instructions for the Clarke-Schopf Cable-Tension Strength Test for knee extension as put forth by Clarke (1) were followed explicitly with the exception of knee angle. The subjects were seated on the quadriceps table with both knee joints at the table edge so the lower legs were hanging down at right angles from the thighs. A folded towel was placed under the tested knee to afford padding. The stirrup was placed around the right calf midway between the knee and the ankle. The cable was then attached to the stirrup and table so that the subject's knee
angle was exactly 120 degrees. McCloy (2) recommended the use of a knee angle of 120 degrees when performing leg lifts and a review of the literature has shown that angle to be approximately the best. After the knee angle was set at 120 degrees, one of the test operators held the subjects' leg down while the other operator attached a tensiometer to the cable and motivated the subject to pull as hard as possible (Figures 1 and 2). Each subject was tested three times with a one minute rest between tests. The average of the three tests was used as the subject's isometric strength score after being converted to pounds of tension with a calibration table.

**Isometric Training.** The subjects stood on the wooden platform with feet shoulder width apart, and the platform hook directly between the feet. The knees were flexed and the bar held at the top of the thighs with the hands (Figure 3). The chain was adjusted so the knees were flexed at an angle of 120 degrees. During the first training session, each subject was told the correct chain link to use so that his knees would always be at the correct angle. The training involved doing three maximal six second isometric contractions with a one minute rest in between contractions, each training session.

**Eccentric Training.** The training method used was mentioned by Banister (3:3). He showed a diagram of the Carlin-Banister Exotronic Ergometer in use and stated:
A force greater than 3000 pounds draws the piston down against the subject's resistance in an eccentric contraction of the leg extensors.

The subjects were placed in the same position as in the isometric training with the exceptions of a knee angle of 160 degrees and a belt used to hold the bar in place (Figure 4). The 160 degree knee angle was chosen as the starting position because of the work of Hugh-Jones (4) who found leg push to increase sharply until a knee angle of 160 degrees was reached and then drop sharply beyond that angle. The control button was held by the subject and when he depressed it, the piston was mechanically pulled down. The subject resisted the downward pull with maximum force until he was pulled to a full squat position at which time he released the button. The subject then released himself and brought the piston back up to the starting position. Three such contractions were performed each training period with a one minute rest in between. The average scores of the first and last training periods were converted to pounds by multiplying by a constant of 2.83 and were used as the pre and post eccentric strength scores for each subject.

Analysis of Data

A one-way analysis of variance was used to determine if differences among the three groups existed in both initial and final isometric scores. Where the F for between groups was
significant, a t-test was used to investigate between group differences. The mean square error from the analysis of variance was used as a pooled estimate of the variance of the three groups.

To determine if significant improvements in eccentric strength took place in the eccentric group, a t-test was computed on the improvement scores in eccentric strength. Further, within the eccentric group, a correlation was computed between improvements in isometric leg strength and improvements in eccentric leg strength. The magnitude of this correlation indicated the degree to which the two improvement scores were related. Because some of the analyses dealt with correlations between scores, the reliability coefficients of individual differences in these scores were also computed.
Figure 1. Isometric Strength Testing with A Cable Tensiometer.
Figure 2. Isometric Strength Testing with A Cable Tensiometer.
Figure 3. Isometric Training with Isometric Apparatus.
Figure 4. Eccentric Training with Carlin-Banister Exotronic Ergometer.
REFERENCES


CHAPTER IV

RESULTS AND DISCUSSION

Results

A statistical description of the physical characteristics of the subjects in each of the three groups is presented in Table II. Inspection of the means and standard deviations for age, height and weight revealed no great variations between groups.

TABLE II

Mean Physical Characteristics of Experimental and Control Groups

<table>
<thead>
<tr>
<th></th>
<th>Age (yrs.)</th>
<th>Height(ins.)</th>
<th>Weight(lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\bar{X}$</td>
<td>$\text{SD}$</td>
<td>$\bar{X}$</td>
</tr>
<tr>
<td>Control Group</td>
<td>21.07</td>
<td>2.55</td>
<td>70.53</td>
</tr>
<tr>
<td>Eccentric Group</td>
<td>22.40</td>
<td>1.67</td>
<td>70.76</td>
</tr>
<tr>
<td>Isometric Group</td>
<td>22.00</td>
<td>3.48</td>
<td>70.46</td>
</tr>
</tbody>
</table>

The group means and standard deviations for the initial and final scores are presented in Table III and Figure 5. Of interest was the apparent improvement of final scores over the initial scores of the two experimental groups while the Control
Pre and Post Group Means of Isometric Strength

Legend:
- Isometric Group
- Eccentric Group
- Control Group

Mean Strength

PRE AND POST GROUP MEANS OF ISOMETRIC STRENGTH
Group failed to show any significant improvement. To aid interpretation of further analysis, a t-test for paired observations was computed on the difference scores of the Control Group. This t was nonsignificant (t = .64) and indicated that the Control Group's isometric leg strength remained essentially the same over the course of the experiment.

**TABLE III**

**Initial and Final Group Strength Means**

<table>
<thead>
<tr>
<th></th>
<th>$M_1$</th>
<th>$SD_1$</th>
<th>$M_2$</th>
<th>$SD_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Group</td>
<td>242.45</td>
<td>45.05</td>
<td>244.26</td>
<td>45.04</td>
</tr>
<tr>
<td>Eccentric Group</td>
<td>239.75</td>
<td>42.37</td>
<td>280.60</td>
<td>38.44</td>
</tr>
<tr>
<td>Isometric Group</td>
<td>241.37</td>
<td>35.00</td>
<td>283.26</td>
<td>39.57</td>
</tr>
</tbody>
</table>

The one-way analysis of variance that was used to determine if the initial strength group means were different, resulted in a nonsignificant F-ratio (Table IV). This indicated the equality of the three groups in their initial isometric strength scores.

An analysis of variance was performed on the final strength group means (Table V). The significant F-ratio for between groups indicated that there was at least one significant difference among the three group means.
TABLE IV

Analysis of Variance of Initial Strength Scores

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>2</td>
<td>27.72</td>
<td>.02</td>
<td>&gt;.05</td>
</tr>
<tr>
<td>Within Groups</td>
<td>42</td>
<td>1683.18</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE V

Analysis of Variance of Final Strength Scores

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>2</td>
<td>7121.65</td>
<td>4.21</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>Within Groups</td>
<td>42</td>
<td>1690.56</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To determine the differences among the groups, t-tests were computed and significant t's (p < .05) resulted when the final scores of the Control Group were compared to those of the two experimental groups (Table VI). The difference between the final scores of the experimental groups was not significant.
TABLE VI
Comparison of Group Means of Final Scores

<table>
<thead>
<tr>
<th>Group Comparison</th>
<th>$M_1$</th>
<th>$M_2$</th>
<th>$M_1 - M_2$</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isometric-Control</td>
<td>283.26</td>
<td>244.26</td>
<td>39.00</td>
<td>7.13*</td>
</tr>
<tr>
<td>Eccentric-Control</td>
<td>280.60</td>
<td>244.26</td>
<td>36.34</td>
<td>6.64*</td>
</tr>
<tr>
<td>Isometric-Eccentric</td>
<td>283.26</td>
<td>280.60</td>
<td>2.66</td>
<td>.49</td>
</tr>
</tbody>
</table>

* Significant at the 5 percent level of significance with 42 df.

The initial and final eccentric strength scores of the Eccentric Group were analyzed with a t-test for matched pairs. A t-value of 5.52 was found to be significant at the .05 level (Table VII).

TABLE VII
Comparison of Initial and Final Mean Eccentric Strength Scores for the Eccentric Group

<table>
<thead>
<tr>
<th></th>
<th>$M_1$</th>
<th>SD$_1$</th>
<th>$M_2$</th>
<th>SD$_2$</th>
<th>$M_2 - M_1$</th>
<th>$SD_2 - SD_1$</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eccentric Strength</td>
<td>907.2</td>
<td>116.90</td>
<td>1281.0</td>
<td>277.10</td>
<td>373.8</td>
<td>262.40</td>
<td>5.52*</td>
</tr>
</tbody>
</table>

* Significant at the 5 percent level of significance with 14 df.

Since some of the analyses dealt with correlations between scores, it was necessary to determine the reliability of
individual differences in these scores. For all groups two improvement scores were calculated by subtracting the second score of the initial three contractions from the second score of the final three contractions, and by subtracting the third score of the initial three contractions from the third score of the final three contractions. Correlations of these improvement scores represented estimates of the reliability of individual differences in strength improvement.

Reliability coefficients revealed significant amounts of individual differences in initial, final and improvement eccentric strength scores (Table VIII). Statistically significant reliability coefficients were also found for individual differences in the initial and final isometric strength scores of all three groups (Table IX). The reliability of individual differences of isometric strength improvement scores for the Control Group and Isometric Group were nonsignificant \((r = -.12\) and \(.20)\), while the individual differences in the Eccentric Group's isometric strength improvement scores were significantly reliable \((r = .69)\).

**TABLE VIII**

Reliability of Eccentric Strength Scores

<table>
<thead>
<tr>
<th>Group</th>
<th>Scores</th>
<th>(r_{xx})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eccentric</td>
<td>Initial</td>
<td>0.79</td>
</tr>
<tr>
<td></td>
<td>Final</td>
<td>0.97</td>
</tr>
<tr>
<td></td>
<td>Improvement</td>
<td>0.81</td>
</tr>
</tbody>
</table>
A correlation coefficient was calculated to determine the relationship between individual differences in isometric and eccentric strength improvement scores in the Eccentric Group. This coefficient showed little relationship between isometric strength improvement and eccentric strength improvement with a nonsignificant $r$ of $0.27$ being obtained (Table X).

Other interesting results, while not having direct implications for the main problems of this study, are summarized in Table X and were as follows:

<table>
<thead>
<tr>
<th>Group</th>
<th>Scores</th>
<th>$r_{xx}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Initial</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>Final</td>
<td>0.97</td>
</tr>
<tr>
<td></td>
<td>Improvement</td>
<td>-0.12</td>
</tr>
<tr>
<td>Eccentric</td>
<td>Initial</td>
<td>0.94</td>
</tr>
<tr>
<td></td>
<td>Final</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>Improvement</td>
<td>0.69</td>
</tr>
<tr>
<td>Isometric</td>
<td>Initial</td>
<td>0.92</td>
</tr>
<tr>
<td></td>
<td>Final</td>
<td>0.59</td>
</tr>
<tr>
<td></td>
<td>Improvement</td>
<td>0.20</td>
</tr>
</tbody>
</table>
### TABLE X

**Correlation Coefficients of Eccentric Group Strength Scores**

<table>
<thead>
<tr>
<th>Strength Scores</th>
<th>r</th>
<th>$r^2 \times 100$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isometric + Eccentric Improvement</td>
<td>0.27</td>
<td>7.10</td>
</tr>
<tr>
<td>Initial + Final Isometric</td>
<td>0.87*</td>
<td>75.90</td>
</tr>
<tr>
<td>Initial + Final Eccentric</td>
<td>0.33</td>
<td>11.12</td>
</tr>
<tr>
<td>Initial Isometric + Eccentric</td>
<td>0.09</td>
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* Significant at the 5 percent level of significance.

1) There were no significant correlation coefficients between initial and final eccentric strength scores, initial isometric and eccentric strength scores, and final isometric and eccentric strength scores.

2) There was a significant relationship between initial and final isometric strength scores.

While statistical significance is a guide to analyzing these data, in the present case where the amount of relationship between two variables was taken as $r^2 \times 100$ (amount of common variance), the only meaningful relationship was the statistically significant one.
Discussion

The results indicated that both experimental groups significantly increased their isometric strength due to the isometric and eccentric training. The isometric strength scores of the Control Group remained relatively constant throughout the testing and training periods thus demonstrating their lack of training.

The percentage of improvement (i.e., mean improvement score/mean initial score x 100) in isometric strength for the Isometric Group and Eccentric Group was respectively 17.4 percent and 17.0 percent. These figures, when taken as percent improvement per week—approximately 3 percent per week—were similar to the percentage of improvement per week (1.79 ± 1.2 percent) for isometric strength found by Hettinger (1) for isometrically trained subjects. An almost twenty percent improvement in initial strength following a six week training program, of quite economical aspects as far as time is concerned, would seem to be quite meaningful and of value to those interested in strength training.

The fact that the Eccentric Group increased their isometric strength through eccentric training did not agree with Petersen (2) who found no increase in isometric strength following eccentric training. However, the extremely low number of subjects (six) used by Petersen made his results questionable.
The increased isometric strength of the Isometric Group through repeated maximal isometric contractions agreed with several earlier studies (3, 4, 5, 6). Taken collectively, these data on isometric training demonstrate that this type of training will undoubtedly increase isometric strength. The only apparent problem left to research will be to further quantify the amount of strength increase in relation to the duration of training and to the initial strength of the subjects.

Many conclusions could have been drawn from the fact that there was no significant difference when the final strength score means of the two experimental groups were compared. It could have indicated that muscle tension is not the most important factor in strength development which would disagree with Hettinger (1) who found muscle tension to be the important factor in muscle training.

The equality of the two experimental groups could also have indicated that eccentric contractions did not produce greater muscle tension than isometric contractions which would disagree with Doss and Karpovich (7). They found eccentric contractions produced 13.5 percent greater force within the muscles than did isometric contractions.

The fact that an isometric test was used to measure improvement of a group that trained eccentrically could have been an additional reason why the Eccentric Group did not show more of an increase in strength per se. Berger (8) has stated
that a statically trained group will show more improvement on a static test than will a dynamically trained group.

The reliability coefficients of individual differences in isometric and eccentric strength scores were generally very meaningful. Most of the present coefficients indicated over eighty percent of the total variance was accounted for by individual differences. The only low reliability coefficients were in the isometric strength improvements for the Isometric and Control Groups. The reason for the low reliability of the Control Group was easily understood. Because there was very little improvement in the Control Group, all subjects had near zero improvement scores thus resulting in there being no individual differences in these scores which in turn caused the very low reliability coefficients. The reason for the low reliability in the Isometric Group was not as easily explained. A scatter diagram of improvement scores (the first improvement score plotted against the second improvement score) revealed no significant trend (a "shotgun" effect) which indicated considerable variability of these scores.

An important point to consider was that the reliability coefficients reported in the results of the present study were minimum values. The majority of the results were computed on the basis of the average of three contractions whereas the reliability coefficients were computed from single scores. The average of several scores has a higher reliability than
the separate single scores.

Correlation coefficients computed between the isometric and eccentric scores of the Eccentric Group were computed from average scores and therefore as mentioned above, individual differences in these scores were more reliable than the actual reported values. Thus the low relationship between the isometric and eccentric strength improvements was not due to low reliabilities. Therefore the low correlations suggested that an improvement in eccentric strength did not necessarily result in a corresponding improvement in isometric strength. This resulted even though group improvements in isometric and eccentric strength were substantial; 17.0 percent and 41.2 percent respectively. This finding agreed with the work of Berger (8) who found no significant relationships \(r = 0.18\) between isometric strength improvements and dynamic strength improvements.

Other findings of interest included the nonsignificant relationship between the initial and final isometric and eccentric strength scores, even though there was high reliability of the individual differences of these scores. It would seem from these results that eccentric and isometric strength are not related and that there is more to the development of strength than just muscle tension. Possibly, it is as Henry and Whitley (9:25) have suggested:

Even maximal static contraction voluntarily initiated is visualized as a neuromotor coordination, capable of being influenced by motivation and a variety of other factors.
The neuromotor integration pattern of such a static contraction might be expected to be different from the more complicated pattern for maximal contraction during movement.

Morehouse as reported by Elliot (10:35) has somewhat agreed with Henry and Whitley and hypothesized:

The training stimulus resides in the central nervous system and the effect of training may be a reduction of the inhibition in the nervous discharges which produce contraction, and therefore the subjects get used to exerting maximum force in this manner.

Elliot (10:45) has also concluded that

... strength in a complex and unfamiliar task is subject to considerable improvement as a result of the learning that results from practice.

These statements would indicate that considerable thought must be given to the concept of the stimulus for strength training. On the one hand, there are investigators (1, 11, 12) who believe that tension is a major factor for increasing strength. The present results while not contradicting this viewpoint suggest an additional important factor. The Eccentric Group which trained eccentrically undoubtedly had great tensions imposed on their leg muscles. While these tensions produced a significant and meaningful group improvement effect in isometric strength, they were almost completely unrelated to the tensions developed during isometric contractions. Therefore, it must be that other factors, in conjunction with induced tension, contribute to
strength improvement. Most likely it is as has been suggested earlier (9:25, 10:35) that the development of complex neuromotor patterns is a prerequisite, as well as a large factor, in determining the development of strength. From this viewpoint then, strength development could be viewed as similar to the development of a motor skill (for which there are also large neuromotor patterns). If this comparison is valid, the specificity of strength improvement as reported in the present experiment could be explained in a similar way to the specificity of motor skills. Henry (13:127) has stated:

Repetition of a motor act improves the specific skill that is practiced but individual differences in ability to profit by practice are specific to that skill and definitely do not predict the ability to improve by practice in some other skill.

Lotter (14:57) found that:

Neuromotor or task specificity implies that individual abilities in performing a specified motor task with a particular group of muscles tend to have only a low correlation with individual abilities in performing a different task using largely the same group of muscles.

It appears that for each motor skill there exists a neuromotor pattern that determines the speed, coordination, etc. of that skill. These neuromotor patterns are completely specific and are not related to any other patterns thus making motor skills highly specific.

In this respect, isometric and eccentric strength can be thought of as being determined, in a large part, by
specific neuromotor patterns that are unrelated to each other. These patterns determine the ability of a subject to coordinate his muscles in a maximal contraction and therefore determine the amount of tension brought to bear in a contraction. Since these neuromotor patterns are specific, it follows that the amount of tension in isometric or eccentric contractions will also be specific.

Thus it is seen that there are at least two factors, both intrinsically responsible for increases in strength. One is the amount of tension produced by a training program which may produce important physiological effects in the muscle that contribute to maximum physiological strength. The other factor is the development of neuromotor patterns which enable subjects to effectively coordinate their muscles to exert tension. Since these neuromotor patterns are specific to the type of contraction performed it is expected that the ability to produce tension isometrically will not be related to the ability to produce tension eccentrically.
REFERENCES


CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

Physical educators have long been interested in strength development and many studies have been undertaken to determine the best method of developing strength. Earlier studies found muscular tension to be of prime importance in strength development and also found eccentric contractions produced the greatest amount of muscular tension. Because of this, the present study was undertaken to see if eccentric contraction strength training would develop leg strength better than an isometric strength training program. The problem of whether eccentric training would produce related isometric and eccentric strength gains was also studied.

Forty-five volunteer university students were systematically assigned to three groups in such a manner that the group's initial isometric leg strengths were equal. These three groups were then randomly assigned to experimental and control conditions. One group trained with eccentric contractions, another with isometric contractions and the last followed control conditions. The groups were all tested before and after a six week training program for isometric leg strength with a Cable-Tensiometer. The Eccentric Group was also tested for eccentric strength with a Carlin-Banister Exotronic Ergometer. The training took place three times per
week and three maximal contractions were performed during each training session.

The results indicated that both the isometric and eccentric training programs produced significant isometric strength gains with t's of 7.13 and 6.64 (p < .05) being obtained when the final scores of the Isometric and Eccentric Groups respectively were compared to the final scores of the Control Group. The amount of improvement from initial to final testing for the Isometric and Control Groups was 17.4 percent and 17.0 percent respectively. A nonsignificant t of .49 (p > .05) was obtained when the final scores of the two experimental groups were compared indicating very little difference between the improvements due to isometric and eccentric training.

Within the eccentrically trained group, eccentric strength was significantly increased due to training (t = 5.52, p < .05) with an improvement of 40 percent occurring. For this group reliability coefficients of .94, .95 and .69 were found for the initial, final and improvement scores, respectively, of isometric strength and the corresponding scores for eccentric strength were .79, .97, and .81. Nonsignificant correlation coefficients of 0.09, -0.05, and 0.27 were obtained for the relationships between initial, final, and improvement scores, respectively, of isometric and eccentric strength scores of this group thus demonstrating little relationship between such scores.
Conclusions

Within the limitations imposed on this study the following conclusions were justified:

1) Both isometric and eccentric training produced significant isometric leg strength improvements.

2) Eccentric training was not significantly better than isometric training for increasing isometric leg strength.

3) Eccentric training produced significant eccentric leg strength improvements.

4) Treating each subject on an individual basis, an increase in eccentric strength due to eccentric training did not necessarily lead to a corresponding increase in isometric strength.

5) There were no significant relationships between isometric strength scores and eccentric strength scores.

Recommendations

1) More experimental studies dealing with the value of eccentric contractions on strength improvement are needed using various training schedules.

2) The question of the specificity of strength in general and specifically the specificity of strength improvements needs further investigation.
3) The theory that neuromuscular coordination can greatly influence strength improvement should be considered in further investigations of strength training.

4) A similar study to the present one should be undertaken in which all subjects are tested eccentrically and trained isometrically. This would determine if transfer occurs from isometric strength to eccentric strength in a similar fashion as the transfer of strength observed in the present study (i.e. from eccentric strength to isometric strength).
BIBLIOGRAPHY


Asmussen, E. "In the Relation Between Length and Tension of the Muscle," Unpublished Paper, University of Copenhagen.


APPENDICES
APPENDIX A
STATISTICAL TREATMENT

A) t-test for between groups

\[ t = \frac{\bar{X}_1 - \bar{X}_2}{S_p \sqrt{\frac{1}{N_1} + \frac{1}{N_2}}} \]

where \( \bar{X}_1 \) = mean of group 1

\( \bar{X}_2 \) = mean of group 2

\( S_p^2 = \text{MS}_E \)

\( S_p = \sqrt{\text{MS}_E} \)

\( \text{MS}_E \) = mean square within groups from analysis of variance

\( N \) = number of subjects within group

B) t-test for paired observations

\[ t = \frac{\bar{d}}{S_d \sqrt{\frac{1}{N}}} \]

where \( \bar{d} \) = mean of difference between paired observations

\( S_d = \sqrt{S_d^2} \)

\( S_d^2 \) = variance of the differences

\( N \) = number of paired observations
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Eccentric Group Isometric Scores

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