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Cross Transfer Effects Utilizing a Unilateral Maximal Isometric Strength Measurement Schedule

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CROSS TRANSFER EFFECTS UTILIZING A UNILATERAL MAXIMAL ISOMETRIC STRENGTH MEASUREMENT SCHEDULE

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by

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CROSS TRANSFER EFFECTS UTILIZING A UNILATERAL MAXIMAL ISOMETRIC STRENGTH MEASUREMENT SCHEDULE

(An Abstract)

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The purpose of this study was to determine the amount of strength transferred to the unexercised contralateral wrist flexor muscle group, utilizing a unilateral maximal isometric strength measurement schedule with college men.

Twenty right handed male college freshmen were selected as subjects for this study. A cable tensiometer and associated equipment was utilized as the measuring instrument for maximal isometric strength of the wrist flexor muscles. Each subject was given a pre-test to obtain the initial strength of each wrist flexor muscle group. Following the pre-test a fourteen day interval was allowed, during which the subjects were placed into two matched groups on the basis of their total pre-test scores. Group "A" was measured with the left hand first for five consecutive days and subsequently with the right hand for five consecutive days. Group "B" was measured in reverse order, right hand to left hand. A two-day rest period separated the five day unilateral measurement programs. All daily treatments consisted of five trials maximal one minute apart, and took place between the time of 10:00 A.M. and 12:00 Noon.

The t-test for paired observations resulted in non-significant t's between the pre-test mean scores and the day one mean scores in

all four unilateral measurement programs. The treatments by subjects analysis of variance design resulted in only the left hand of group "A" demonstrating a statistically significant strength change. In this unilateral program only day one differed significantly from days two, four, and five.

As non-significant t's occurred between the pre-test mean scores and the day one mean scores of the second measured hand, it was concluded that no cross transfer of strength occurred.

On the basis of the data and within the limitations of this study the following conclusions seem warranted:

1. The repeated maximal isometric measurement schedules of short duration are satisfactory in a reliability sense for measuring the maximal strength of the wrist flexor muscles in a test re-test situation fourteen days apart.

2. The repeated maximal isometric measurement schedules are not capable of eliciting significant increases in strength potentialities of the exercised muscles during a five day measurement program.

3. No transfer effects of strength potentialities to the contralateral limb resulted as the exercised muscle group itself failed to demonstrate a significant increase in exerted strength.

ACKNOWLEDGMENTS

The writer wishes to express his sincere appreciation to Dr. Walter Kroll for his interest, suggestions, and criticisms which aided materially in the successful completion of this work; to the other members of the committee, Dr. James Belisle, Dr. Gordon Price, and Mr. Dennis McKee; and to the students of Fort Hays Kansas State College who willingly participated as subjects for the study.

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CHAPTER I

INTRODUCTION

For centuries man has been attempting to measure accurately physical strength and to devise the best methods possible, in terms of exercise programs for increasing innate potentialities. The first recorded attempt in this measurement area was performed by a French scientist, DeLaHire, who in 1699 compared the strength of men lifting weights.[1]

Since the time of DeLaHire many changes have occurred in the various succeeding studies regarding the procedures and techniques used to best measure human strength. Probably the greatest single advancement in this area has been the introduction of instruments for measuring and recording with exacting precision the strength of various muscle groups in the human body.

Today there are several instruments available to isolate and measure the force exerted by the individual muscle groups in man. The cable tensiometer, adapted by Clarke[2] for measuring

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[1] DeLaHire, M. Examen de la force de l'homme, Memoires de l'Academie Royale des Sciences, 12:153-162, November 14, 1699, cited by Paul A. Hunsicker and Richard J. Donnelly, "Instruments to Measure Strength," Research Quarterly, 26:408-419, December, 1955.

[2] H. Harrison Clarke, "A Comparison of Instruments for Recording Muscle Strength," Research Quarterly, 24:398-411, December, 1954.

muscular strength, is one of the most valid and reliable instruments presently available for isometric strength measurement. The tensiometer measures a static muscular contraction exerted on a cable. The exerted force records in tensiometer units on a dial in the instrument to be used by the tester.

The methods of exercise used for strength measurement vary, in that some instruments require an isotonic type exercise while other instruments measure the strength exerted by an isometric muscular contraction.

The type of muscular exercise program which brings about the largest increase in muscular strength is now in question. Until a few years ago, the isotonic progressive resistance exercise employed by DeLorme[3] was commonly accepted as the best method for increasing human strength. However, in 1946, Hellebrandt[4] theorized that the isometric method would bring about a greater gain in strength than could the isotonic method because during isometric exercise the muscle could develop

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[3]T. L. DeLorme, "Restoration of Muscle Power by Heavy Resistance Exercise," Journal of Bone and Joint Surgery, 27:645-667, 1945, cited by Robert E. Jones, "Reliability of the Ten Repetition Maximum for Assessing Progressive Resistance Exercise," Journal of the American Physical Therapy Association, 42:661-662, October, 1962.

[4]F. A. Hellebrandt, "Recent Advances in Methods of Hastening Convalescence Through Exercise," Southern Medical Journal, 39:398-401, May, 1946, cited by Philip J. Rasch, "Progressive Resistance Exercise: Isotonic and Isometric: A Review," Journal of the Association for Physical and Mental Rehabilitation, 15:245-56, March-April, 1961.

maximum tension while at its resting or optimum length. In 1953, Hettinger and Mueller[5] demonstrated that a single isometric exercise of two-thirds maximal effort maintained for approximately five seconds daily brought about a five per cent gain weekly in initial strength. Since these two introductory studies many other researchers have attempted to compare the strength gains brought about by the two methods. There are conflicting results from these studies as to which method will produce the greater gains; however, the conclusion is that by either of the two methods, gains in strength occur when an individual exercises at certain levels of effort.

The one facet of strength which will be dealt with in this paper is the cross transfer effect of isometric strength, obtained by using a unilateral measurement schedule, to the contralateral limb. The first study concerned with the cross transfer effect was conducted by Scripture,[6] who in 1894, concluded that by practicing the skill of writing with one hand --

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[5]T. Hettinger and E. A. Mueller, Muskelleistung and Muskeltraining. Arbeitsphysiologie, 15:111-126, 1953, cited by Philip J. Rasch, "Progressive Resistance Exercise: Isotonic and Isometric: A Review," Journal of the Association for Physical and Mental Rehabilitation, 15:2:45-56, March-April, 1961.

[6]E. W. Scripture, et. al., "On Education of Muscular Control and Power," Studies Yale Psychological Laboratory, 2:114-119, 1894, cited by F. A. Hellebrandt, et. al. "Cross Education-The Influence of Unilateral Exercise on the Contralateral Limb," Archives of Physical Medicine, 28:76-85, 1947.

the contralateral hand also increased in the skill. Welch's[7] study in 1898, found that cross transfer effects occurred from the non-dominant to the dominant hand, but not the reverse, in volitional muscular exercise of both hands. Davis,[8] in 1899, theorized that cross transfer occurs because of an 'overflow' of nervous impulses into the unexercised arm.

Since these early studies regarding the cross transfer of strength, many other experiments have been completed utilizing both isotonic and isometric measurement schedules. The findings of the various studies are of a conflicting nature due in part to the unrelated types of measurement schedules, different muscle groups studied, and variations in the number of subjects and actual procedures used in the studies.

In the studies which have positively demonstrated this cross transfer of strength effect, there are several theories available as to the cause of the transfer effects of increased muscular strength to the contralateral muscle groups. However, there will need to be additional research conducted employing

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[7]J. C. Welch, "On the Measurement of Mental Activity Through Muscular Activity and the Determination of a Constant of Attention," American Journal of Physiology, 1:283-306, 1898, cited by F. A. Hellebrandt, et. al., "Physiological Effects of Simultaneous Static and Dynamic Exercise," American Journal of Physical Medicine, 35:106-117, 1956.

[8]W. W. Davis, "Researches in Cross Education," Studies Yale Psychological Laboratory, 6:6-50, 1899, cited by Franklin M. Henry and Leon E. Smith, "Simultaneious vs. Separate Bilateral Muscular Contractions in Relation to Neural Overflow and Neuromotor Specificity," Research Quarterly, 32:1:42-46, March, 1961.

similar procedures and having highly correlated results occurring before any definite statements can be produced concerning this cross transfer effect.

Purpose of study. The purpose of this study was to determine the amount of strength transferred to the unexercised contralateral wrist flexor muscle group, utilizing a unilateral maximal isometric strength measurement schedule with college men.

Significance of study. This study was significant in that it was the first study to use an established reliable method of assessing human strength. Kroll,[9] in his study to determine the reliability of an individual for exerting maximal isometric effort with the wrist flexor muscles, found that a single daily program of five trials one minute apart gives an intraclass correlation reliability coefficient of .9315. Continuing this single daily program for three consecutive days, Kroll's subjects demonstrated an intraclass correlation reliability coefficient of .9546.

Working with various daily schedules of isometric strength, Kroll[10] found no significant change occurring in the exerted strength of the measured wrist flexor muscles when the subjects were subjected to a test re-test situation, having a fourteen-day interval between the two testing days.

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[9]Walter Kroll, "Reliability of a Selected Measure of Human Strength," Research Quarterly, 33:3:410-418, October, 1962.

[10]Walter Kroll, "A Reliable Method of Assessing Isometric Strength," Research Quarterly (in press).

The preceding information allowed this investigator to obtain an accurate initial strength measurement upon which to base any changes or variations in the exerted strength of the individual subjects. This includes both the exercised muscle group and the contralateral muscles.

With additional research being conducted in this area of strength development, it is becoming more evident that good physical strength is one of the major factors needed for a sound body. Physical educators have been using strength tests as a method of classifying students within classes, determining total physical condition, and indicating individual growth. Clarke states that:

> The improvement of muscular strength is also a basic necessity in the development of physical fitness, as strength is generally conceded to be a basic component of physical fitness.[11]

Motor coordination, as an individual's ability to correctly perform organic skills, is also related to strength. Willgoose[12] found that in various large muscle activities the skill involved in performing these activities is affected by the muscular strength of the individual. Other factors such as height, weight,

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[11] H. Harrison Clarke, "Development of Volitional Muscle Strength as Related to Fitness," (Paper Presented at the Colloquium of Exercise and Fitness, Robert Allerton Park, Monticello, Illinois, December, 1959).

[12] Carl E. Willgoose, "The Relationship of Muscular Strength to Motor Coordination in the Adolescent Period," <u>Journal of Educational Research</u>, 45:138-142, October, 1950.

and age being equal the less muscular strength an individual possesses, the lower will be his proficiency in performing motor skills.

Muscular speed, being closely related to motor coordination, is also thought to be affected by an individual's organic strength. In the past years many people associated with physical education erroneously believed that to increase one's muscular strength brought about a decrease in the muscle's contractile speed. By using weight lifters and non-weight lifters as subjects for their study, Zorbas and Karpovich[13] found that increasing muscular strength, concurrently increased the exercised muscles' speed.

The need for exercise programs in today's elementary and secondary schools to increase muscular strength is illustrated by Jones,[14] who points out that approximately four-fifths of an adult's strength, but less than one-third of his height is obtained after the age of six years. Galton[15] concluded that

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[13]William S. Zorbas and Peter V. Karpovich, "The Effect of Weight Lifting Upon the Speed of Muscular Contractions," Research Quarterly, 22:145-148, May, 1951.

[14]Harold E. Jones, Motor Performance and Growth, University of California Press, Berkeley, California, 1949, p. 181, cited by Paul Hunsicker and George Greey, "Studies in Human Strength," Research Quarterly, 28:109-122, May, 1957.

[15]Francis Galton, et. al., Report of the Anthropometric Committee. Report of the British Association for the Advancement of Science, 225-272, 1881, cited by Paul Hunsicker and George Greey, "Studies in Human Strength," Research Quarterly, 28:109-122, May, 1957.

muscular strength in males increases rapidly from ages twelve to nineteen, then tapers off, increasing regularly but at a lower rate up to age thirty, then decreases gradually until approximately age sixty.

People in the fields of physical medicine and rehabilitation are extensively using exercise programs for the corrective development of losses in strength, due to illness or injury. Rudd[16] criticized the procedure of using maximal resistance exercise with orthopedic patients because of the possibility of a muscle or ligament strain. Luck[17] in direct contrast to Rudd, observed no adverse effects to a weak muscle when it was subjected to a maximal amount of resistance.

The use of isometric exercise for these patients would seem feasible in that a large movement of the injured limb would not be needed. If the patient has the ability to exert a static contraction with the involved limb, then, there is present the potentiality for increases in strength within the injured muscles. But with isotonic exercises the involved limb passes through a

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[16] J. L. Rudd, "Resistance Exercises in Private Practice," Archives of Physical Medicine and Rehabilitation, 36:775-778, December, 1955, cited by Philip J. Rasch, "Studies in Progressive Resistance Exercise: A Review," Journal of the Association for Physical and Mental Rehabilitation, 12:4:125-130, July-August, 1958.

[17] J. Vernon Luck, "Orthopedic Rehabilitation," Air Surgeon's Bulletin, 2:431-433, December, 1945, cited by Philip J. Rasch, "Studies in Progressive Resistance Exercise: A Review," Journal of the Association for Physical and Mental Rehabilitation, 12:4:125-130, July-August, 1958.

greater range of movement; thus many weakened limbs could not participate in this type of exercise.

In a study conducted at the Chelsea Naval Hospital, using orthopedic patients and the static type exercise, Dr. Haslam pointed out that isometric measurement has the advantage of allowing the patients to exert effort on a cable tensiometer, as used, for enough time so that it is possible to determine which muscles are in a state of tension. Progress toward recovery, in terms of increasing muscular strength, could also be accurately recorded in these cases of rehabilitation.[18]

The cross transfer effects from unilateral strength measurement programs have unlimited opportunities in rehabilitation work. By having the patient perform a regular strength measurement program, either isotonically or isometrically, with the uninvolved limb, he may create potentialities for increasing the strength of the muscles and prevent a loss of strength and atrophy from occurring in the involved limb.

Procedures. The subjects used in this study were twenty college freshman men, who could meet the investigator at the designated time for the required number of days. All subjects

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[18]H. Harrison Clarke, "Objective Strength Tests of Affected Muscle Groups Involved in Orthopedic Disabilities," Research Quarterly, 19:118-147, May, 1948.

professed to be right handed. These men were given a pre-test (five trials, one minute apart, exerting maximal effort), with both the right and left wrist flexor muscle groups. Following the pre-test the subjects were randomly assigned by pairs into two matched groups, "A" and "B", on the basis of their combined pre-test scores. Between the pre-test and the twelve day testing program, a two-week rest period was allowed during which time no instructions or training for any other formal strength measurement programs was given.

During the twelve day testing program, group "A" was tested the first week with the left hand, and then with the right hand the second week of testing. Group "B" was tested in reverse order, right hand to left hand. The daily testing for each individual consisted of five trials maximal, one minute apart. No subject was allowed to exert a force for more than five seconds during each trial. The mean score for the five daily trials was the criterion measure used that day.

Regarding the pre-test as having an effect upon the measured strength at the beginning of the twelve day measurement program, Kroll[19] and Hettinger[20] found that by having a two week (fourteen days) interval between measurement days there is no

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[19]Kroll, "A Reliable Method of Assessing Isometric Strength."

[20]Theodor Hettinger, Physiology of Strength (Springfield, Illinois: Charles C. Thomas, Publisher, 1961), p. 30.

significant change in the exerted strength when measured isometrically. The preceding information allowed this investigator to rule out the possibility of a learning or training effect creating a significant change in the initial strength of the measured muscles due to the pre-test.

The instrument used in this study for measuring isometrically the wrist flexor muscles was the cable tensiometer. Clarke,[21] in a study designed to compare the advantages of several measuring instruments, found the cable tensiometer to be the most accurate and reliable of all the instruments tested.

Morris[22] constructed an apparatus, utilizing the tensiometer to measure only the right wrist flexor muscles. Ray[23] altered this apparatus so that both the right and left wrist flexor muscles could be measured isometrically. This altered apparatus was then used as the measuring instrument in the present study.

Standardized instructions were read to each subject daily, regarding procedures to be followed and encouraging a maximal effort on each trial.

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[21]Clarke, "A Comparison of Instruments for Recording Muscle Strength."

[22]Harold H. Morris, "The Effect of Order Upon a Selected Measure of Human Strength" (Unpublished Master's thesis, Fort Hays Kansas State College, August, 1961).

[23]Arthur L. Ray, "Cross Transfer Effects of Isometric Strength Measurement Schedules" (Unpublished Master's thesis, Fort Hays Kansas State College, July, 1962).

Delimitations. The present study was delimited to include only the right and left wrist flexor muscle groups of twenty subjects. The study was delimited to include a pre-test, a single maximal isometric strength measurement program of five trials one minute apart for both wrist flexor muscle groups, two weeks prior to a twelve day testing program. The twelve day testing program consisted of: five consecutive days of testing with one hand, a two day rest period, then five consecutive days of testing with the other hand. The number of daily unilateral treatment trials was delimited to five, one minute apart. All daily testing occurred within a two hour period, 10:00 A.M. to 12:00 noon.

Limitations. This study was limited in size to include only twenty subjects. The muscle group selected for study was limited to include only the wrist flexor muscles of both arms. The total measurement program was limited to four weeks including: a one day pre-test (five trials one minute apart with each hand) given two weeks in advance of the actual testing program for determining the initial strength of the wrist flexor muscle group of both arms; a fourteen day rest period; and two weeks of testing -- five consecutive days of testing with one hand, followed by a two day rest period, then five consecutive days of testing with the contralateral hand. Each daily unilateral treatment was limited to five trials one minute apart. The daily testing time was limited to include two hours, 10:00 A.M. to 12:00 noon.

Summary. Today, with the increased emphasis being placed on muscular development, there is need for more definite evidence as to the effectiveness of various types of measurement programs on strength development.

The purpose of this paper was then to determine the amount of gained strength transferred to the unexercised contralateral wrist flexor muscle group in a selected measure of muscular strength. The exercise program used in this study was a unilateral maximal isometric strength measurement program exerted five times a day, one minute apart, employing the wrist flexor muscles.

This study was significant in that it was the first study to utilize an established reliable method of assessing isometrically the strength of the wrist flexor muscle group. The intraclass correlation reliability coefficient found by Kroll for a single daily treatment of five trials one minute apart was .9315, by continuing this treatment for five consecutive days the intraclass correlation reliability coefficient was .9564.

Twenty right-handed college freshman men were used as subjects for this study. After taking a pre-test, including both the right and left wrist flexor muscle groups, the subjects waited two weeks, were then tested for five consecutive days with one hand, rested two days, and then were tested for five consecutive days with the contralateral hand.

The instrument used for measuring and recording the exerted strength was a cable tensiometer secured in an apparatus, so as to isolate and measure only the wrist flexor muscle group during the measurement bouts.

CHAPTER II

REVIEW OF RELATED LITERATURE

If one has examined literature related to human strength and the development of it, he has found that there are a number of individual or separable factors involved in the total strength area. An individual's strength is directly associated with his total organism. The person's physiological, psychological, social, and moral values play an important part in the way an individual will seek to further develop his innate muscular abilities.

Body structure and sex also control to a degree the development of strength within an individual. Sills and Everett,[1] using individuals of extreme somatotypes in their study pertaining to motor and strength tests, found mesomorphs to be stronger than ectomorphs and endomorphs; also, the mesomorphs surpassed the other two groups in tests of speed, agility, and endurance. In performing physical activity of this nature excess weight is a handicap to endomorphs, while an insufficient amount of strength in an ectomorph lowers his level of performance.

In regard to sex, Hettinger[2] found that women are less trainable in terms of muscular development than are men; also that

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[1]Frank D. Sills and Peter W. Everett, "The Relationship of Extreme Somatotypes to Performance in Motor and Strength Tests," Research Quarterly, 24:223-228, May, 1953.

[2]Hettinger, op. cit., pp. 10-11.

maximum muscular trainability occurs in men from twenty to thirty years of age. Mueller[3] concluded that women's muscles respond to training stimuli less than do the corresponding muscles of men.

Ikai and Steinhaus[4] indicate that the end point or upper level of any physical performance is determined by either a psychological or physiological limit. In strenuous activities the psychological limit is nearly always reached first preventing further activity, thus performance is predominately limited by this factor. The psychological limits vary within individuals, causing unreliable individual performances within repeated daily activities and succeeding activity. However, the physiological limit, being the unmeasurable capacity an individual possesses, is relatively stable and seldom reached by many individuals performing strenuous physical activities.

INSTRUMENTS TO MEASURE STRENGTH

The use of precision instruments is of unlimited value in any measurement area, as the quantities which are subjected to investigation must be accurately scored and recorded. The area of strength measurement is by no means an exception to this rule.

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[3]Erich A. Mueller, "The Regulation of Muscular Strength," Journal of the Association for Physical and Mental Rehabilitation, 11:41-46, March-April, 1957.

[4]Michio Ikai and Arthur H. Steinhaus, "Some Factors Modifying the Expression of Human Strength," Journal of Applied Physiology, 16:1, 1961.

The development of instruments used for strength measurement has occurred primarily within the past one hundred and fifty years. We now have instruments which measure with a large degree of reliability and validity the strength exerted by either a static (isometric) or a dynamic (isotonic) type of measurement. For this study a cable tensiometer, an instrument for measuring static strength was employed.

During the Second World War the cable tensiometer, a small compact recording instrument, was used to measure the tension placed on cables in airplanes. Clarke,[5] employing the same type tensiometer, adapted it to record the static strength exerted by an individual on a one-sixteenth inch cable secured in the tensiometer. In a study comparing the advantages of several measuring instruments, Clarke found the cable tensiometer to be the most valid and reliable instrument of those tested for strength measurement. It is primarily due to Clarke's work that the cable tensiometer is now widely used in studies employing static strength. The cable tensiometer used in this study records the exerted force in tensiometer units from 0 to 100. Conversion tables are present to allow the unit scores to be changed into pounds (0 to 200); however, for this study the tensiometer unit scores were retained for calculating procedures.

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[5]Clarke, "A Comparison of Instruments for Recording Muscle Strength."

The cable tensiometer does not record a complete isometric measurement, in that a small movement is caused by the cable passing between two offset terminals. The movement of the cable is so minute that for measurement purposes the exerted force is considered to be an isometric measurement.

ISOMETRIC MEASUREMENT PROGRAMS AND STRENGTH

At present there are two main types of measurement programs, the isometric method and the isotonic method. The isometric or static measurement can be defined as "a static muscle contraction is held for a designated length of time,"[6] while the isotonic or dynamic type measurement occurs as "the muscle continues to raise or lower a submaximal load."[7] A muscle exerting a force isometrically is said to not shorten or change its length; however, a static measurement can bring about a shortening of the involved muscle by ten per cent of the muscle's length and still be considered as an isometrically exerted force.[8]

It is believed by some authorities that a muscle has potential for exerting its maximal strength if the length of the muscle can

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[6]Clarke, "Development of Volitional Muscle Strength as Related to Fitness," loc. cit.

[7]Ibid.

[8]Peter Karpovich, Physiology of Muscular Activity (Philadelphia: W. B. Saunders Company, 1953), p. 13.

remain unchanged and at its optimum length. The Weber-Fick law, as illustrated by Arkin,[9] states "that muscle fibers are shortened to one-half their extended length in full physiological contraction." Also brought out in his study, utilizing the quadriceps muscles of dogs, is that the tension developed at maximum extension is approximately three times that developed at maximal flexion. This exemplifies that maximal potentials for muscle tension occur much greater when the muscle is at maximum extension rather than maximum flexion. Hellebrandt,[10] in 1946, proposed the theory that a muscle will develop maximum tension when the resistance is so heavy that it will not allow the muscle to shorten. Since isometric measurement permits no change in muscle length, outside the alloted ten per cent range, it is widely accepted and used as a method of exercise for increasing and improving strength.

It has also been found that the slower a muscle contracts the greater the potentialities for strength increases will be. Hill[11]

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[9] Alvin M. Arkin, "Absolute Muscle Power, The Internal Kinesiology of Muscles," Microcarded Master's Thesis, State University of Iowa, Iowa City, June, 1939.

[10] F. A. Hellebrandt, "Recent Advances in Methods of Hastening Convalescence Through Exercise," <u>Southern Medical Journal</u>, 39:398-401, May, 1946, cited by Philip J. Rasch, "Progressive Resistance Exercise: Isotonic and Isometric: A Review," <u>Journal of the Association for Physical and Mental Rehabilitation</u>, 15:2:46-50, March-April, 1961.

[11] A. V. Hill, "Voluntary Muscle -- The Mechanics of Its Active State," <u>The Times Review of the Progress of Science</u>, 1:13, August, 1951, cited by Philip J. Rasch and Richard V. Freeman, M.D., "The Physiology of Progressive Resistance Exercise: A Review," <u>Journal of the Association for Physical and Mental Rehabilitation</u>, 8:2:35-42, March-April, 1954.

states that "the mechanical efficiency (work/total energy) of muscles is greatest at about one-fifth of the maximum speed."

Employing the principles of the amount of time spent in exercise and the percentage of maximal strength which must be exerted to bring about maximal strength gains using isometric measurements, Hettinger[12] found that exerting one maximal contraction of one to two seconds daily brought about the maximum trainability of a muscle. Maximal effort is not needed to create maximum muscle strength. Hettinger found that only forty to fifty per cent of maximal effort is needed; however, this force must be exerted for a longer period of time. An exertion of two-thirds maximal must be held for approximately four to six seconds to elicit the maximum strength potentialities in a muscle, with one exertion per day being sufficient to create maximum muscular strength. Royce[13] found that the required tension needed to elicit maximal strength development must be above sixty per cent of maximal effort. This is in contrast to a study of Mueller's[14] in which, by utilizing one-third and two-thirds maximal efforts, he found maximal development in the amount of strength produced

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[12]Hettinger, _op. cit._, pp. 24-28.

[13]Joseph Royce, "Isometric Fatigue Curves in Human Muscle With Normal and Occluded Circulation," _Research Quarterly_, 29:204-212, May, 1958.

[14]Mueller, _loc. cit._

occurring with the two-thirds maximal measurement program; however, no increase in strength occurred with the one-third maximal exertions. Mueller then suggested the level of forty per cent maximal as the level above which an increase in effort brings about no additional increase in strength. Mueller related that stimuli or exertions below twenty per cent maximal do not prevent atrophy from occurring. Exertions between twenty and thirty-five per cent maximal prevent atrophy from occurring but do not create muscular training. Exertions above thirty-five per cent of maximal induce muscular training and create increases in strength within the exercised muscles.

PROGRAMS FOR INCREASING STRENGTH

In studies related to the number of isometric contractions needed daily to elicit the greatest change in muscular strength there are conflicting results occurring.

Concerned with the increase of muscular strength and endurance, Liberson and Asa[15] found, by comparing single maximal isometric contractions of six seconds duration each day against repeated (twenty trials daily) maximal isometric contractions, that the repeated contractions produced better results with the endurance factor. Both programs elicited increases in muscular strength.

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[16]W. T. Liberson and Maxim Asa, "Further Studies of Brief Isometric Exercises," Archives of Physical Medicine and Rehabilitation, 40:330-336, 1959.

Asa,[17] working with daily single and repeated maximal isometric measurement programs, found that the repeated (twenty trials daily) measures of the abductor muscles in the little finger of the right hand gave a significantly greater increase in muscular strength than did the single daily measurements.

Mayberry[18] employed two programs of single daily isometric contractions during a training period of five days a week for five weeks. One program consisted of single maximal exertions and the other of repeated fifty per cent maximal exertions. Upon completion of the measurement program neither isometric method employed had produced a significant increase in the strength of the exercised muscles.

Utilizing single isometric measurements of two-thirds maximal effort, three days a week, with the elbow flexor muscle group, Rasch and Morehouse[19] found at the cessation of a six weeks training program no significant changes in strength occurring within the exercised muscle group.

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[17] M. Maxim Asa, "The Effects of Isometric and Isotonic Exercises on the Strength of Skeletal Muscles," Dissertation for Degree Doctor of Physical Education, Springfield College, Springfield, Massachusetts, June, 1959.

[18] Robert P. Mayberry, "Isometric Exercise and the Cross Transfer of Training Effect as it Relates to Strength," College Physical Education Association, 155-158, December, 1958.

[19] Philip J. Rasch and Laurence E. Morehouse, "Effect of Static and Dynamic Exercise on Muscular Strength and Hypertrophy," Journal of Applied Physiology, 11:1:29-34, July, 1957.

Employing two groups of subjects in their study, Rarick and Larsen[20] utilized daily isometric measurements for the wrist flexor muscles. One group used a single two-thirds maximal contraction daily and the other group worked with exertions of eighty per cent maximal. The group employing the eighty per cent maximal effort used five trials on Monday and increased the number of trials one each day till Thursday when they employed eight trials; however, the exertions remained at the eighty per cent level. The fifth day each week was used for testing maximal effort. At the conclusion of the eight weeks testing program, it was found that both programs produced a significant increase in strength; however, there was no significant difference between the groups regarding increased strength within the exercised muscles.

Utilizing repeated isometric measurements of both maximal and two-thirds maximal efforts for strength development, Walters[21] found, at the end of an eight day testing period, that the maximal strength measurement method created greater increases in strength than did the two-thirds maximal group. Both measurement methods created significant increases in the strength of the exercised muscles.

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[20] G. L. Rarick and Gene L. Larsen, "Observations of Frequency and Intensity of Isometric Muscular Effort in Developing Static Muscular Strength in Post-Pubescent Males," Research Quarterly, 29:333-341, October, 1958.

[21] C. Etta Walters, et. al., "Effect of Short Bouts of Isometric and Isotonic Contractions on Muscular Strength and Endurance," American Journal of Physical Medicine, 39:4:131-141, August, 1960.

Selecting the lower back muscle group for study, Berger[22] compared static and dynamic measurement programs in the amount of increase in muscular strength each created within the selected muscle group. The isometrically trained group exercised with repeated maximal exertions three days a week for twelve weeks. Upon cessation of the twelve weeks program the two groups were each given a static and dynamic strength test. The results showed that both the isotonic and isometric exercise methods of measurement elicited significant increases in strength within each of the post-testing methods.

Measuring the strength of the wrist flexor muscles with repeated maximal isometric contractions for five consecutive days, Darcus and Salter[23] found no consistent increase in strength during the first week of testing. However, a second week of training created an apparent increase in exerted strength. The reason given for this delay in the indicated strength increase is that the change occurred due to a learning nature on the part of the subject, that is the subject learned through practice to exert a maximal effort on the recording instrument.

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[22]Richard A. Berger, "Comparison of Static and Dynamic Strength Increases," Research Quarterly, 33:3:329-333, October, 1962.

[23]H. D. Darcus and Nancy Salter, "The Effect of Repeated Muscular Exertion on Muscle Strength," Journal of Physiology, 129:325-336, January, 1955.

CROSS TRANSFER EFFECTS

The cross transfer effects of strength to the contralateral limb is one facet of strength development which is relatively new in research. Scripture,[24] Welch,[25] and Davis[26] were among the first investigators who conducted studies to find if this phenomena existed and to what extent. Since their time various research has been conducted with a large quantity of material written on the subject. However, the results of the studies and the written material vary greatly in accordance to the existence and quantity of the cross transfer effects of strength.

Employing electromyograph readings to ascertain the cross transfer of strength potentialities, Olsen[27] used isotonic measurements of varying percentages of effort in the forearm flexor muscles. As the per cent of maximal effort increased the amount of activity in the contralateral muscles increased also, with the maximum activity recorded at or near the maximal effort on the part of the exercised muscles. To create a strength potentiality in the unexercised muscle an effort of 67.9 per cent of maximal

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[24] Scripture, loc. cit.

[25] Welch, loc. cit.

[26] Davis, loc. cit.

[27] Frank D. Sills and A. L. Olsen, "Action Potentials in Unexercised Arm When Opposite Arm is Exercised," Research Quarterly, 29:2:213-221, May, 1958.

must be employed in the exercised muscles. The maximum action potentialities created in the unexercised arm were less than those created in the exercised muscles, when the exercised limb moved against no resistance. Sills and Olsen[28] found that by exerting an isotonic force seventy per cent of maximal, electrical potentialities are elicited in the contralateral limb. These results indicate that resistance of a high percentage of maximal is necessary to create electrical potentialities in the contralateral limb.

Panin[29] conducted a study in which he measured the activity potentialities in the unexercised antagonistic muscles by the use of an electromyograph. A measurement program was used employing isotonic flexion of the elbow and knee. Panin's results show that activity produced in the unexercised muscles was never found to be more than twenty per cent of the potentialities in the exercised muscles. This being the case, the potentialities in the unexercised muscles never reaches a level at which an exercise or a strength increase effect will occur if Mueller's theory is accepted, that a potentiality must be thirty-five per cent of maximal before an increase in strength is possible.

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[28] Frank D. Sills and A. L. Olsen, "Action Potentials in Unexercised Arm When Opposite Arm is Exercised," Research Quarterly, 29:2:213-221, May, 1958.

[29] N. Panin, et. al., "Electromyographic Evaluation of the Cross Exercise Effect," Archives of Physical Medicine and Rehabilitation, 42:47-56, January, 1961.

In a study to determine cross transfer effects, Hellebrandt[30] employed both dynamic and static measurement programs. The dynamic and static measures consisted, respectively, of wrist extension treatments on an ergograph, and of holding a stable resistance with the wrist in extension. It was found that cross transfer effects occurred from the non-dominant to the dominant limb.

Working with three groups, one using maximal isometric measurements, one with two-thirds maximal isometric measurements, and one with isotonic measurements, Walters[31] found that the maximal isometric group was the only one in which a significant increase in strength occurred to the contralateral limb. The theory presented here is that transfer occurs when work is performed in overload or maximal.

Davis[32] studied the muscle stimulations recorded in various unexercised muscles when a unilateral muscular exertion of sub-maximal effort took place. Davis' results showed that the greatest amount of remote stimulations is located in the contralateral limb. The activity stimulations in the contralateral limb vary in quantity with the per cent of exertion in the exercised limb; however, the stimulations in the contralateral limb are always lower than those in the exercising limb.

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[30]F. A. Hellebrandt, et. al., "Physiological Effects of Simultaneous Static and Dynamic Exercise," American Journal of Physical Medicine, 35:106-117, 1956.

[31]Walters, loc. cit.

[32]R. C. Davis, "The Pattern of Muscular Action in Simple Voluntary Movement," Journal of Experimental Psychology, 31:5:347-366, November, 1942.

Employing the antagonistic muscles as the specific group upon which to check for transfer of strength, Rasch[33] used the elbow flexor and extensor muscle groups in his study. By exercising with maximal isometric effort a significant increase in the strength of the antagonistic muscles occurred after a six weeks measurement program.

Darcus and Salter,[34] utilizing both maximal isometric and isotonic measurements of the wrist muscles in their study, found that upon completion of the measurement program an increase occurred in both the isometric and isotonic strength of the contralateral limb. No significant difference occurred between the amount of strength transferred with the two groups.

Mayberry[35] experimented with the aspect of cross transfer of strength by using programs of maximal and fifty per cent maximal isometric contractions on the wrist flexor muscles. No statistically significant increase in the strength of the exercised muscles occurred at the end of a five weeks measurement program. Cross transfer effects of strength could not be expected to be found in the unexercised contralateral muscles, if the exercised muscles themselves did not increase in strength.

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[33]Philip J. Rasch, "The Effect of Isometric Exercise Upon the Strength of Antagonistic Muscles," The Biokinetics Research Center, University of California at Los Angeles, April, 1961.

[34]Darcus and Salter, loc. cit.

[35]Mayberry, loc. cit.

To determine if cross transfer of strength occurs within the abductor muscles of the little finger, Asa[36] employed both isotonic and isometric measurement programs. The isometric measures were maximal single and repeated daily programs. The results found no cross transfer of strength occurring.

Rasch and Morehouse[37] utilized isotonic and isometric strength measurements of the elbow flexor muscles to determine if cross transfer of strength occurs. Upon cessation of the measurement program no significant changes in strength occurred in either the exercised or non-exercised muscle groups of those subjects employing the isometric exercises. However, with the isotonic measurement method, a significant strength increase occurred in both the exercised and contralateral limb.

Studying the factor of various days per week for measurement programs, Kruse and Mathews[38] employed four separate isometric programs during a period of four weeks. The programs were one to exercise two days a week, one three days a week, one four days a week, and one five days a week. The results indicated that measurement programs need to be conducted at least three times a week, as the group being measured only twice a week showed no statistically significant increases in strength in either the

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[36]Asa, _loc. cit._

[37]Rasch and Morehouse, _loc. cit._

[38]Robert Kruse and Donald Mathews, "Bilateral Effects of Unilateral Exercise: Experimental Study Based on 120 Subjects," _Archives of Physical Medicine and Rehabilitation_, 39:371-376, June, 1958.

exercised or contralateral limb. The groups being measured three, four, and five times a week showed statistically significant gains in the strength of the exercised arm. An increase in the strength of the contralateral limb failed to appear within any of the measurement programs.

It is difficult to explain with a degree of accuracy the actual causes for cross transfer of strength occurring. Davis[39] concluded that as there is a widespread pattern of activity occurring in the accessory muscles during a volitional muscular movement, "the true unit of activity must be not the flexing or extending of a particular muscle or limb but an adjustmental design in which many regions of the organism participate." Walshe[40] feels that cross transfer occurs primarily in heavy resistance exercises, in that tonic postural reflexes from the central nervous system creates potentialities in the associated muscle groups, of which the contralateral group is included. If the potentialities reach a specified level in the contralateral limb, there is the possibility for strength increases to occur.

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[39]R. C. Davis, "The Pattern of Response in a Tendon Reflex," Journal of Experimental Psychology, 30: , June, 1942, cited by Frank D. Sills and A. L. Olsen, "Action Potentials in Unexercised Arm When Opposite Arm is Exercised," Research Quarterly, 29:2:213-221, May, 1958.

[40]F. Walshe, "On Certain Tonic or Postural Reflexes in Hemiplegia with Special Reference to the So-Called "Associated Movements," Brain, 46:1, 1923, cited by Robert Gregg, "Cross Exercise - A Review of the Literature and Study Utilizing Electromyographic Techniques," American Journal of Physical Medicine, 36:269-280, 1957.

Hellebrandt[41] in 1947, postulated that the principle reasons for a cross transfer of strength to occur might be a diffusion of motor impulses to both the exercised and the contralateral limb, and the development of a reflex pattern related to the maintenance of the individual's balance. It is commonly known that postural readjustments regarding balance always occur when an individual is subjected to heavy resistance of a unilateral nature. Possibly then cross transfer depends only on the volume of impulses transmitted to the contralateral limb, due in part to the per cent of maximal which the resistance consists of in the measurement program.

SUMMARY

Measurement programs either of the isotonic or isometric type are now accepted as methods of developing strength within the exercised muscle groups. The conflicting results which have been presented in this chapter raises the question as to which of the two methods is more beneficial for increasing strength. In studies previously completed both methods have brought about significant strength gains in the exercised muscle groups of the subjects.

The percentage of effort needed to create strength increases is not definitely known; however, forty per cent of maximal is believed to be the lowest level which will elicit strength increases

[41]F. A. Hellebrandt, "Cross Education: Ipsilateral and Contralateral Effects of Unimanual Training," Journal of Applied Physiology, 4:136-144, August, 1951.

in the exercised muscles. It is indicated that repeated daily trials and measurement treatments three, four, and five days a week have produced significant strength gains more consistently than have single daily trials and treatments of two or less a week.

In studies having found a significant cross transfer of strength effect occurring, the exercised muscles were measured at maximal or near maximal effort and also increased significantly in strength. In measurement programs where the exercised muscles have failed to increase significantly in strength, the demonstration of any cross transfer effects failed to occur. It is only when the exercised muscles show significant gains in strength that the cross transfer effects have been demonstrated.

Two reasons other than actual strength increases are given to possibly explain the increases in the recorded strength scores. One is the learning ability of the individual subject for exerting a maximal effort on the instrument. In this case the increased scores would not represent actual strength or muscle development, rather the learning ability of the subject. Another is the ability of the subject to increase his resistance to fatigue and pain during the measurement trials thus raising his daily scores. The factor here, as is found in other types of studies involving human subjects is the psychological attitude of the individual subject. It would appear that until we find a method of eliminating the psychological factor, studies involving human participation will be subject to question regarding their validity and reliability.

Researchers, in the selection of subjects for a study, should be aware that strength increases are subject to individual differences as weak muscles increase rapidly in strength to a level which allows normal daily activity without a tiring effect on the individual; then the increase is regular, but at a much lower rate, till a plateau at or near maximal effort is reached. If only athletes are utilized the resulting strength increases may be non-existent or small in quantity, due to the high degree of development already present in the measured muscles. In contrast, subjects who are severely limited in their daily exercise may demonstrate large strength increases which also are misleading. For these reasons the subjects should be randomly selected from a large sample which will allow individuals of varying strength development to be employed in the study. If this procedure is followed it is probable that the obtained results will reflect the entire population in regard to the material under investigation.

CHAPTER III

METHODS AND PROCEDURES

The purpose of this chapter is to present the methods and procedures employed in this study. The chapter is sub-divided into four specific areas involved in the total testing program. The included areas are a description of the subjects, testing equipment, testing procedures, and the analysis of data.

Description of subjects. Twenty male Fort Hays Kansas State College freshmen were used as subjects for this study. The subjects selected were those who could meet with the investigator at the designated time for the required number of days. All subjects professed to be right handed. The age, height, and weight of each subject was recorded at the time of the pre-test. Table I presents descriptive data regarding the age, height, and weight of the subjects.

TABLE I

AGE, HEIGHT, AND WEIGHT OF SUBJECTS
(n = 20)

	Age	Height	Weight
High	20 yrs., 2 mo.	6 ft., 3 in.	195 pounds
Low	18 yrs., 0 mo.	5 ft., 8 in.	130 pounds
Range	2 yrs., 2 mo.	7 in.	65 pounds
Mean	18 yrs., 5 mo.	5 ft., $10\frac{1}{2}$ in.	160 pounds
Median	18 yrs., 7 mo.	5 ft., 11 in.	158 pounds
Standard Deviation	7.5 mo.	1.75 in.	16.3 pounds

The subjects, throughout the study, did not participate in any other formal type of measurement program other than a required physical education class, Fundamentals of Sports I, which met two days a week. All subjects displayed a co-operative attitude toward the study and appeared to exert their maximal effort during each daily trial. The general decrease in the exerted strength from trial one to trial five during the daily treatments tended to substantiate the preceding statement.

Testing equipment. As was indicated in Chapter I, any study involving a measurement factor requires a precision instrument to accurately score and record these measures. The cable tensiometer was selected as the instrument most appropriate for this type of study. The tensiometer used in this study was a model T5-6007-114-00, which recorded exerted isometric efforts in tensiometer units with a range of 0-100. The conversion of the tensiometer scores into pounds will give a range of 0-200. The cable tensiometer is a compact instrument which records, on a calibrated dial, the static tension placed on an offset riser located between two stable sectors. A one-sixteenth inch flexible cable, upon which the force is exerted, passes between the riser and two sectors. As tension is exerted, isometrically by the subject on the cable, the force is simultaneously recorded on the instrument. The scores are recorded as tensiometer units and for this study these units were retained for the analysis of data.

As the wrist flexor muscle groups were to be measured for their maximal exerted strength, it was necessary then to place the wrist in a state of hyper-extension during the testing periods. Placing the wrist in a hyper-extension position was made possible by having a series of chain links secured to one end of the cable. In order to adjust the cable to the correct length for each subject, the handle was attached to a definite chain link where it remained throughout the entire measurement program.

An apparatus was constructed by Morris[1] including the cable tensiometer and related equipment to isometrically measure the strength of the wrist flexor muscles of the right hand. Ray,[2] altered this device to allow the flexor muscles of both wrists to be measured. The described instrument, being used in the two previously mentioned studies and the present study, is designed to incorporate procedures employed by Clarke.[3] In these procedures the tensiometer is aligned at a ninety degree angle to the cable to allow for a maximal exertion by the subject and an accurate measurement of the exerted force.

In order to isolate the muscle group under observation the measured limb must be held completely stationary. This was accomplished by securely strapping to a restraining board the

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[1]Morris, loc. cit.

[2]Ray, loc. cit.

[3]H. Harrison Clarke, "Objective Strength Tests of Affected Muscle Groups Involved in Orthopedic Disabilities," Research Quarterly, 19:118-147, May, 1948.

forearm of each individual subject being tested. Any movement of the forearm during the testing could possibly cause an increase in the recorded score, thus invalidating the test and its results. Foam padding was placed between the straps and the forearm to prevent needless discomfort to the subject during testing. Figures I and II illustrate the equipment arrangement and the subject's position during the actual measurement program. Measurement with the right hand is shown on page 37 and left hand measurement is shown on page 38.

During each measurement treatment the subjects, keeping both feet on the floor and the unexercised hand in the lap, were seated in front of the instrument in a standard straight back chair. A stop watch was used to time the one minute interval between trials and also to see that no subject exerted a force for longer than five seconds during each trial.

Testing procedures. This study was significant in that it employed an established reliable method of assessing human strength and that a pre-test was given to determine the initial wrist flexor muscle strength. The pre-test consisted of a one day measurement program measuring the maximal isometric strength of both hands, with each hand exerting five trials maximal, one minute apart. Following the pre-test a fourteen day interval or rest period was given to the subjects.

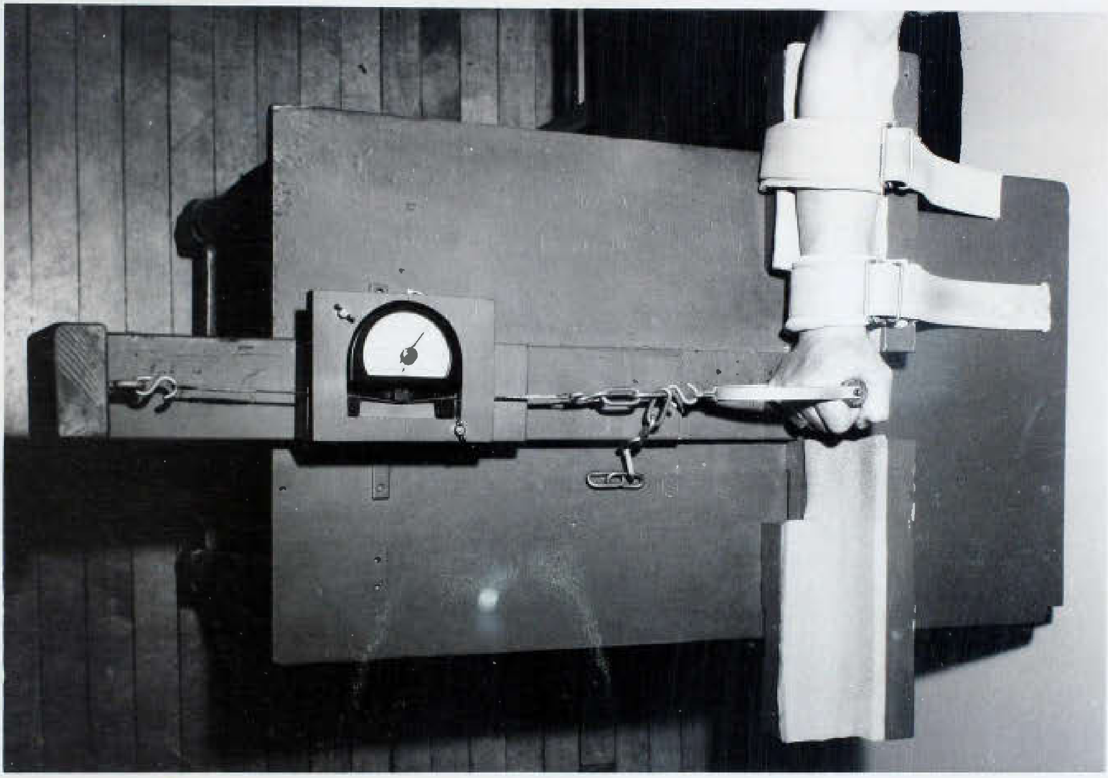

FIGURE I

POSITION OF SUBJECT
DURING RIGHT HAND MEASUREMENT

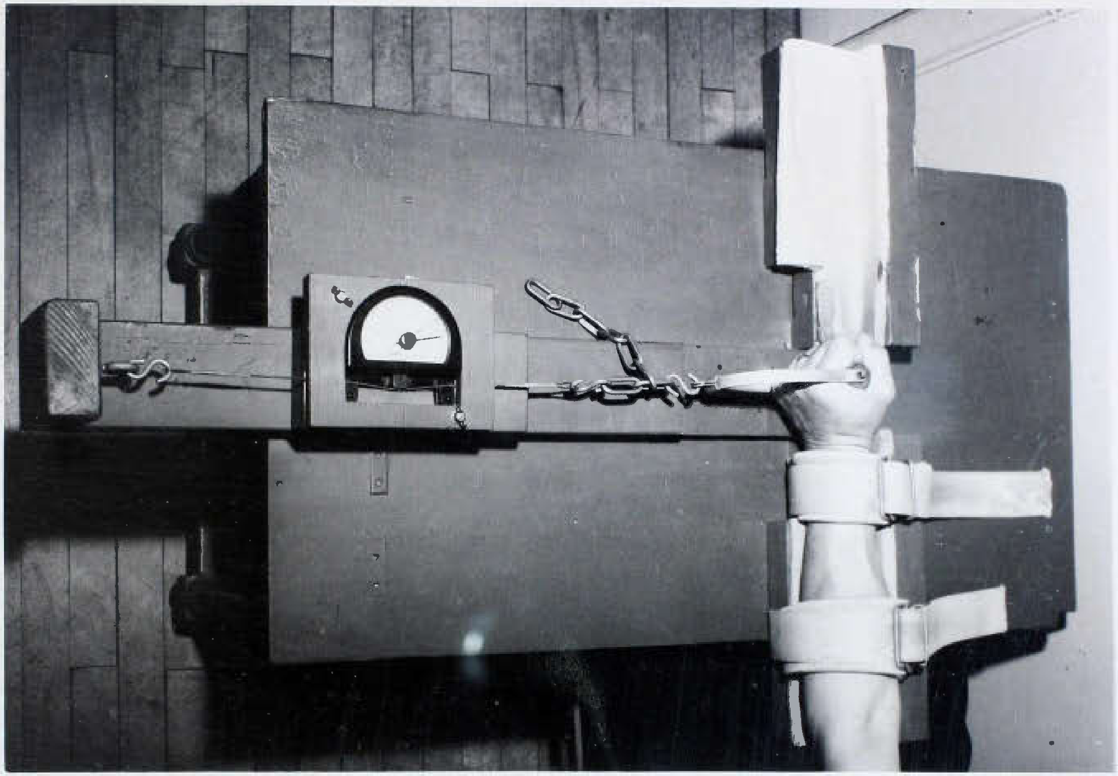

FIGURE II

POSITION OF SUBJECT
DURING LEFT HAND MEASUREMENT

Hettinger[4] and Kroll[5] have previously found that changes in strength due to either a learning or practice effect from a one-day measurement program will be lost in fourteen days.

Upon completion of the pre-test the subjects were randomly assigned by pairs, on the basis of their combined right and left hand pre-test scores, into one of two groups, "A" or "B". After the fourteen day interval the subjects were tested on successive days as follows: group "A" was tested for five consecutive days with the left hand, followed by a two-day rest period, then again tested for five consecutive days with the right hand. Group "B" followed the same schedule in regard to the number of days tested, but were measured in a reverse order, going from the right hand to the left hand. Each group was composed of ten subjects. An individual daily testing treatment consisted of five trials maximal, one minute apart with one hand. The hand tested was determined by the group to which the subject belonged. The program began October 22, 1962, and was completed December 14, 1962.

As a variation in the time of day to test for maximal strength might bring about masking effects, an attempt to standardize the measurement time for each subject was followed. Wright,[6] in a study to determine if a duirnal pattern exists in

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[4]Hettinger, loc. cit.

[5]Kroll, "A Reliable Method of Assessing Isometric Strength."

[6]Verna Wright, "Factors Influencing Duirnal Variation of Strength of Grip," Research Quarterly, 30:110-116, March, 1959.

relation to strength tests, found a definite pattern of variation. Exerted strength increases regularly from early morning (approximately 6:00 A.M.) till about 12:00 Noon or 1:00 P.M., then decreases gradually until during the night hours when there is a pronounced decrease in the exerted strength of an individual. In this study all testing occurred between the hours of 10:00 A.M. and 12:00 Noon, utilizing the potentially best daily time for measuring maximal strength. In this study each subject reported daily within a previously designated hourly interval to be tested, either between 10:00 A.M. to 11:00 A.M. or 11:00 A.M. to 12:00 Noon.

During the pre-test and the two weeks measurement program, each subject was asked to, if necessary, remove his coat and roll up his shirt sleeve to elbow height, to allow the forearm to be securely strapped to the instrument.

The following standardized instructions were read to each subject before the pre-test:

Pre-test: This study is to determine the strength of the wrist flexor muscles of both arms. For this study to be a success each subject must exert an all out effort on each trial.

1. You will be seated on the chair in front of the instrument, keeping both feet on the floor, and the unexercised hand in your lap throughout the test.

2. The tested arm will be firmly strapped to the instrument with your hand gripping the handle.

3. When I give the command you are to pull with a steady maximal effort until you have exerted an all out effort, five seconds approximately.

4. You will be given five trials using the right (or left) hand, with a one minute rest period between each trial,

during which time you should relax your grip on the handle. After this you will be given time to change your position from the right to left hand (or vica versa) for further testing.

5. Further testing will include five trials, one minute apart with the other hand.

6. Are there any questions?

On each succeeding test day the following instructions were given to the individual subjects:

<u>Succeeding test days</u>: Today you will only be tested with your right (or left) hand. You will be given five trials with a one minute rest period between each trial. The procedure will follow the same as was previously given you.

1. Remember to exert a maximal effort on each trial.

2. Are there any questions?

The subjects were also instructed not to brace their feet against the table legs or other objects and to keep the unexercised hand in the lap at all times. These measures were to further insure that the wrist flexor muscles were isolated and the only ones in a contractile state of tension during the trials. There is a remote possibility, despite these precautions, that an interaction of associated muscle groups may occur. Upon completion of the instructions the subject's forearm was secured to the apparatus and the testing began. During the one minute rest period the subjects relaxed their grip on the handle and sometimes stretched the fingers to prevent cramps or fatigue from excessively occurring.

All testing and data collecting occurred in a private office at the Division of Health, Physical Education, and Recreation at Fort Hays Kansas State College. During the entire program, only the tester and subject were present for the testing treatments. This eliminated the possibility of having the presence of another individual eliciting or inhibiting the responses made by the subject. An attempt was made to keep the environmental conditions standardized, thus, no motivational devices of any type were used, other than requesting each subject to exert his maximal effort on each trial. Talking between the investigator and the subject occurred at normal tones to prevent excitation within the subject.

The subjects during testing were able to observe their recorded scores; however, the investigator never reported a score to either the subject being tested or to any other subject. The only tangible extrinsic variables were the occasional talking of people and the ringing of a telephone in another office.

Analysis of data. To aid in the analysis of the obtained data, graphs and tables were utilized to illustrate changes occurring in the recorded scores of the subjects during the complete program.

The treatments by subjects design described by Lindquist[7] was used in the data analysis. This design is desirable in studies of this type in which the treatments are administered in successive

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[7]E. F. Lindquist, *Design and Analysis of Experiments in Psychology and Education* (Boston: Houghton Mifflin, 1953), pp. 156-163.

order to the same subjects. The primary reason for utilizing the treatments by subjects design was to increase the precision of the study by eliminating inter-subject differences as a source of error. In using this method of data analysis, only one criterion score is needed for each subject during each daily treatment. In this study the mean score of the five daily trials, for the individual subject, was used as the criterion score for the given day.

Being the primary purpose of this study to determine the amount of cross transfer of increased strength to the contralateral wrist flexor muscle group, a pre-determined level of significance was selected upon which to base the results and conclusions. The five per cent level of significance was selected in order to determine whether the (if any) strength increases in the measured muscles and the cross transfer effects were significant. Thus, all results and conclusions from this study were dependent upon the five per cent level of significance.

<u>Summary</u>. Twenty male college freshmen served as subjects for this study. All subjects professed to be right handed. A pre-test was given all subjects to determine the maximal initial strength of the wrist flexor muscles of both hands. Following the pre-test a fourteen day rest interval was given, during which the subjects were assigned on the basis of their total pre-test scores, into one of two measurement groups for the study. Standardized procedures and instructions were given to each subject before the pre-test and each daily treatment. The actual testing program

consisted of a twelve day period, five consecutive days of testing with one hand, a two day rest period, and five consecutive days of testing with the contralateral hand. Group "A" was tested the first week with the left hand and with the right hand during the second week; group "B" was tested in the reverse order, right hand first and the left hand second. Each daily testing treatment consisted of five trials maximal, one minute apart, employing unilateral exertions. All testing occurred between 10:00 A.M. and 12:00 Noon. The mean score of the five daily trials was used as that day's score in the analysis of data.

A cable tensiometer and associated equipment was secured in an apparatus for measuring isometrically the maximal strength of the wrist flexor muscles. To isolate the muscle group under study, the forearm of the measured limb was immobilized by securely strapping it to a restraining board. The measurement program took place in a private office, with only the subject and the tester present.

The treatments by subjects design was used in the analysis of data. The primary reason for using this analysis method was that it eliminates the inter-subject variation and creates more exacting precision. The level of significance upon which the results and conclusions were determined was placed at the five per cent level of confidence.

CHAPTER IV

RESULTS AND DISCUSSION

The results of this study regarding the effect of repeated maximal isometric strength measurement schedules of short duration upon the strength of the measured wrist flexor muscles and the contralateral muscle group will be presented in this chapter. Included will be the stability of measurement from the pre-test to the first testing day, the day effect upon changes in exerted strength, the cross transfer effects, a discussion of the results, and the conclusions.

Pre-test vs. day one testing. Table II presents the mean, standard deviation, and range of the recorded scores from all subjects during the pre-test and the day one testing treatment. In analyzing the data to determine if a significant change in the recorded strength scores occurred between the two testing days, pre-test and day one, a t-test for paired observations was run.[1] Having selected the five per cent level of significance upon which to base the results, a t of 2.262 was required to constitute a significant difference in exerted strength.

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[1]Allen L. Edwards, Statistical Methods for the Behavioral Sciences (New York: Rinehart & Company, Inc., 1956), pp. 275-282.

TABLE II

SUMMARY OF PRE-TEST AND DAY ONE SCORES (n = 10)

GROUP "A"

	Left Hand		Right Hand	
	Pre-test	Day One	Pre-test	Day One
Mean	45.82	46.08	48.10	47.30
Standard Deviation	6.09	6.51	5.62	4.45
High	57.9	59.8	57.6	53.3
Low	33.6	33.2	41.0	39.4
Range	24.3	26.6	16.6	13.9

GROUP "B"

	Left Hand		Right Hand	
Mean	48.25	48.98	47.24	47.86
Standard Deviation	7.00	7.59	7.57	5.93
High	60.9	62.2	63.8	58.9
Low	38.9	39.4	35.9	40.8
Range	22.0	22.8	27.9	18.1

As Table III presents, the obtained t's were as follows: group "A" right hand pre-test to day one .75, left hand pre-test to day one -.81; group "B" right hand pre-test to day one -.55, left hand pre-test to day one -1.52. Since not one of the four obtained t's approached the level of significance, any fluctuations occurring between the two measurement days were accepted as due to a chance effect.

Effect of days. Tables VI and VII, found in Appendixes A and B, present the mean, standard deviation, and range of all scores included in the four unilateral strength measurement programs. In group "A" the left hand mean tensiometer scores fluctuated from 46.08 on day one to 44.10 on day five, the right hand from a mean score of 47.30 to a score of 46.14. The fluctuations in mean scores for group "B" were with the right hand 47.86 on day one to 47.36 on day five, the left hand from 48.98 to 47.49. The largest variation in the recorded mean scores for individual days in any one week was with the left hand of group "A", where on day one the mean score was 46.08 and on day four 43.25, a range of 2.83 tensiometer units. The greatest variation between mean scores of day one and day five also occurred in group "A" where the left hand on day one recorded a mean score of 46.08 and on day five recorded a mean score of 44.10, a difference of 1.98 tensiometer units.

Figures III and IV present graphically the mean scores for both the right and left hands of groups "A" and "B" respectively, including the pre-test and the two weeks unilateral maximal isometric strength measurement program.

TABLE III

STABILITY OF PRE-TEST SCORES
TO DAY ONE SCORES
(n = 20)

GROUP "A"

	Right Hand		Left Hand	
	Pre-test	Day One	Pre-test	Day One
Mean Scores	48.10	47.30	45.82	46.08
Standard Deviation	5.62	4.45	6.09	6.51
t	.75		-.81	

GROUP "B"

Mean Scores	47.24	47.86	48.25	48.98
Standard Deviation	7.57	5.93	7.00	7.59
t	-.55		-1.52	

FIGURE III

MEAN STRENGTH TENSIOMETER SCORES
PRE-TEST AND TWO WEEK TESTING PROGRAM

GROUP "A"

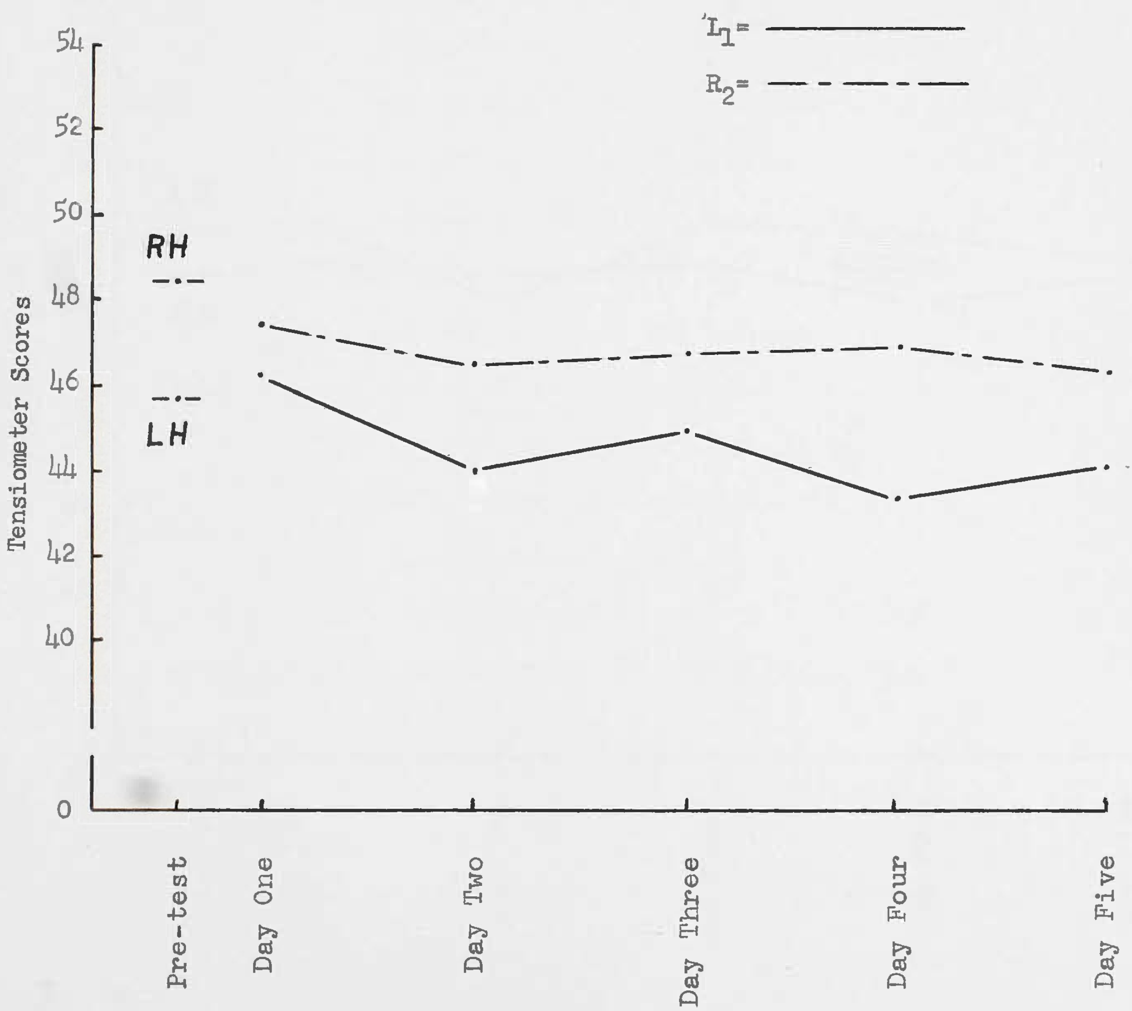
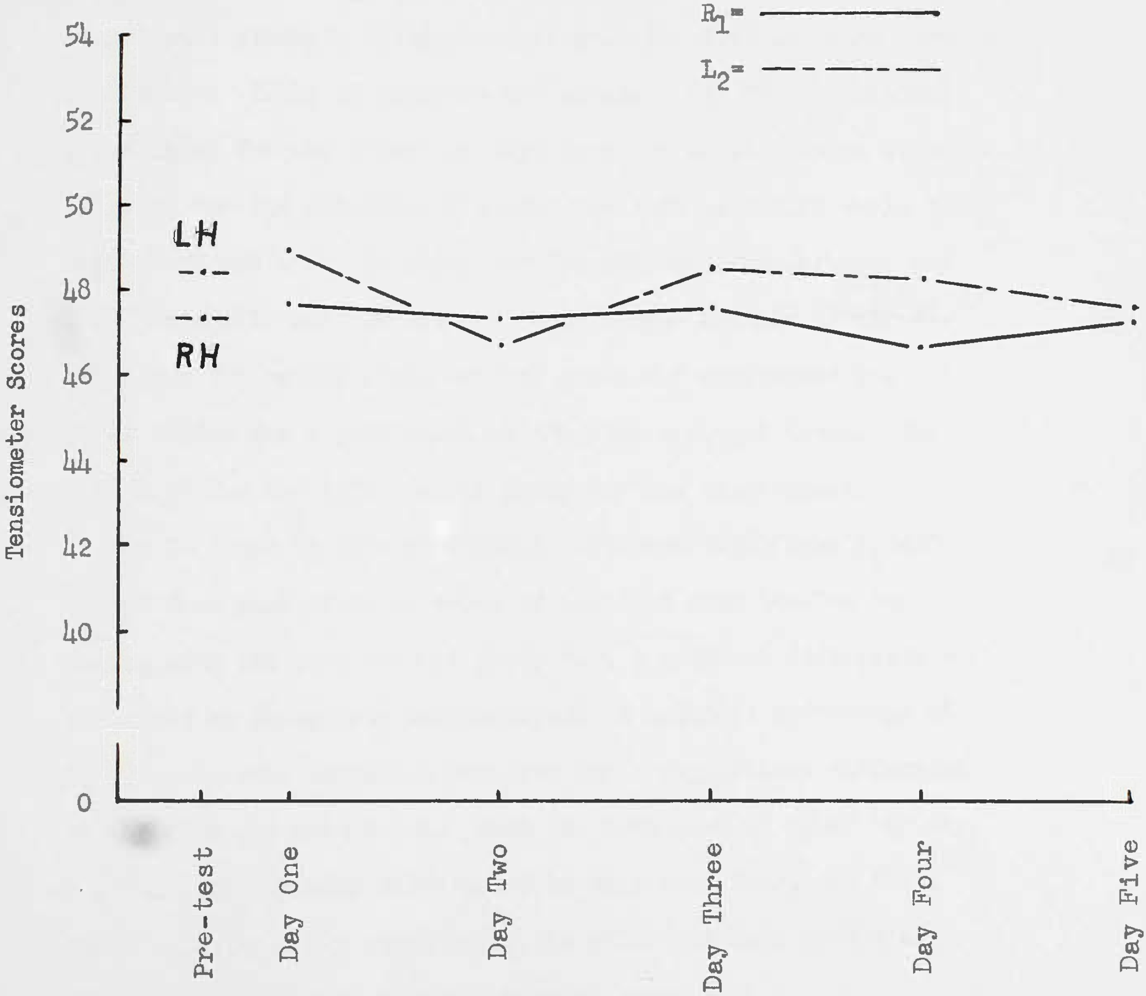


FIGURE IV

MEAN STRENGTH TENSIOMETER SCORES
PRE-TEST AND TWO WEEK TESTING PROGRAM

GROUP "B"



Analysis of data. To determine if any changes in the daily strength mean scores from day one to day five were significant, an analysis of variance employing the treatment by subjects design was made.[2] Utilizing this analysis method and with four and thirty six degrees of freedom, an F of 2.69 was needed to have a significant strength change occurring at the five per cent level of confidence. Table IV presents the obtained F's for the analysis of variance for the effect of days upon the wrist flexion strength. In group "A" the resulting F's were the left hand 2.90 while the right hand was .55. In group "B" the obtained F's were for the right hand 2.17 and for the left hand 1.65. Neither of the F's for group "B" or the right hand of group "A" approached the level needed for significance at the five per cent level. The F of 2.90 for the left hand of group "A" was significant.

In order to determine which days were significantly different from each other in terms of recorded mean tensiometer scores with the left hand of group "A", a critical difference test described by Lindquist[3] was employed. A critical difference of 1.82 tensiometer units was required for a significant difference at the five per cent level. With the left hand of group "A" day one was significantly different from days two, four, and five. Table V presents the results for the effect of days upon wrist flexion strength with the left hand of group "A".

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[2]Lindquist, loc. cit.

[3]Lindquist, op. cit., pp. 93, 166.

TABLE IV

ANALYSIS OF VARIANCE OF THE EFFECT OF DAYS
UPON WRIST FLEXION STRENGTH

GROUP "A"

Left Hand

	df	ss	ms	F
Days	4	46.31	11.58	2.90
Subjects	9	1265.95	140.66	-
Residual	36	143.50	3.99	
Total	49	1455.76		

Right Hand

	df	ss	ms	F
Days	4	8.89	2.22	.55
Subjects	9	781.15	86.79	-
Residual	36	146.61	4.07	
Total	49	936.65		

GROUP "B"

Right Hand

	df	ss	ms	F
Days	4	28.68	7.17	2.17
Subjects	9	1194.26	132.69	-
Residual	36	118.50	3.29	
Total	49	1341.44		

Left Hand

	df	ss	ms	F
Days	4	30.19	7.55	1.65
Subjects	9	2422.51	269.17	-
Residual	36	165.05	4.58	
Total	49	2617.75		

TABLE V

RESULTS OF t-TEST FOR THE EFFECT OF DAYS
UPON WRIST FLEXION STRENGTH
(Group "A")

Left Hand					
	Day I	Day II	Day III	Day IV	Day V
Day I	-	2.07*	1.16	2.83*	1.98*
Day II	-	-	.91	.76	.09
Day III	-	-	-	1.67	.82
Day IV	-	-	-	-	.85

*Significant at the five per cent level of confidence.

Cross transfer effects. The maximal unilateral isometric strength measurement program as employed in this study did not produce a cross transfer effect of strength to the contralateral limb. This statement was verified as non-significant strength changes were found between the pre-test mean scores and the day one mean scores of both the measured limb and the contralateral limb.

Discussion of the results. This study being the first to employ an established reliable method of assessing maximal isometric strength can verify the obtained results regarding changes in the mean recorded strength scores of the subjects within the five day unilateral maximal isometric strength measurement program and for the cross transfer of strength to the contralateral limb. The pre-test served as a reliable criterion measure upon which to base any significant strength changes between the pre-test and day one and any cross transfer of strength to the contralateral limb. Ray,[4] in his study indicated that a possible cross transfer effect occurred from the non-dominant to the dominant hand but not the reverse. This appeared as the daily mean scores for the dominant right hand, when measured second, were consistently higher than the daily mean scores of the first measured non-dominant left hand. However, by failing to utilize a pre-test and by not placing his subjects into matched groups for the unilateral isometric strength measurement program, Ray could only assume these possibilities due to the daily mean scores of the subjects. It is entirely possible that by randomly assigning the subjects to the two measurement groups as Ray did and by not having an initial strength score for each subject, there was present the chance that one group of his subjects was significantly stronger initially with one hand, in this case the dominant right hand.

Even though a significant increase in strength may occur within a five day unilateral isometric strength measurement program and a significant difference between the non-dominant and dominant hand also may occur, unless a reliable pre-test is employed as a criterion measure and the subjects are separated into matched groups no definite conclusions can be made regarding the cross transfer of strength.

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[4]Ray, loc. cit.

In this study the non-significant t's which occurred between the pre-test mean scores and the day one mean scores (two weeks apart) verified the stability of the criterion program measurement schedule. Also the non-significant t's between the pre-test mean scores and the day one mean scores (three weeks apart) of the contralateral limb, suggested no cross transfer of strength occurred.

The results of this study causes one to question previous studies which have reported significant cross transfer of strength, and yet did not employ a reliable pre-test to obtain an initial strength measurement of the muscle groups under study. It is only by utilizing the pre-test, for obtaining the initial strength of the involved muscle groups, and placing the subjects into matched groups for the unilateral isometric strength measurement program that an investigator may definitely conclude whether or not any significant cross transfer effects occurred to the contralateral limb.

The analysis of variance employed for determining the day effect upon strength found that no significant increases in strength occurred within any of the unilateral measurement programs. Within three of the unilateral measurement programs no significant changes occurred in mean scores from day one to day five. The left hand of group "A" demonstrated a significant change; day one being significantly different from days two, four, and five. However, days two, four, and five were significantly lower than day one, indicating a significant decrease from day one to day five.

The learning and training or practice theories which have been introduced to possibly explain significant increases in strength scores are questionable in view of the results from this study. These theories are questionable for in this study no significant strength change occurred between the pre-test mean scores and the day one mean scores for any of the four unilateral isometric strength measurement programs. The training or practice theory was refuted because day five was never significantly greater than day one within any of the four measurement programs. In the program which demonstrated a significant difference between day one and day five, day five was significantly lower.

The results of this study substantiate previous studies[5,6,7,8] that before any cross transfer effects of strength are possible to the unexercised contralateral limb, the exercised limb or muscles must demonstrate a significant increase in strength. Before any convincing generalizations can be presented, studies demonstrating a significant improvement in exercised muscles must be required. Then checks to assess cross transfer effects would be appropriate.

The present study failed to demonstrate a significant improvement in the exercised unilateral limbs. Hence the appearance

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[5]Asa, loc. cit.

[6]Mayberry, loc. cit.

[7]Rasch and Morehouse, loc. cit.

[8]Kruse and Mathews, loc. cit.

of a cross transfer effect would have to have been ascribed to motor learning phenomena. Since no cross transfer effects occurred it is cautiously advanced that no motor learning took place under the utilized isometric strength measurement schedule.

Conclusions. The following conclusions are presented on the basis of the resulting data obtained from this study:

1. The repeated maximal isometric measurement schedules of short duration are satisfactory in a reliability sense for measuring the maximal strength of the wrist flexor muscles in a test re-test situation fourteen days apart.

2. The repeated maximal isometric measurement schedules are not capable of eliciting significant increases in strength potentialities of the exercised muscles during a five day measurement program.

3. No transfer effects of strength potentialities to the contralateral limb resulted as the exercised muscle group itself failed to demonstrate a significant increase in exerted strength.

Summary. The t-test for paired observations found the maximal isometric strength measurement program to be stable in measuring the strength of the wrist flexor muscles.

The five day measurement program failed to elicit a consistent increase within the mean strength scores for any of the four unilateral measurement groups. The F test used in the analysis of data found non-significant changes occurring within three of the four unilateral isometric strength measurement programs; both the right and left hand of group "B" and the right hand of group "A". The left hand of group "A" demonstrated a significant change in exerted strength, however, this change was a decrease in mean scores from day one to day five.

Since a non-significant strength increase occurred in the exercised muscles, transfer effects of strength to the unexercised contralateral muscle groups are not deemed possible in this study.

CHAPTER V

SUMMARY

The purpose of this chapter is to summarize this study which deals with the transfer effects of gained strength to the contralateral limb. The summary includes the purpose, significance, methodology, results, conclusions, and recommendations.

Purpose. The purpose of this study was to determine the amount of strength transferred to the unexercised contralateral wrist flexor muscle group, utilizing a unilateral maximal isometric strength measurement program with college men.

Significance. This study was significant in that it was the first study to use an established reliable method of assessing isometrically the strength of the wrist flexor muscles, both within a single daily program (five trials one minute apart) and a five day continuation of this daily treatment.

The study was also significant as the pre-test allows the tester an accurate initial strength measurement for both wrists of each subject. Utilizing the fourteen day interval between the pre-test and measurement program, any change in strength within the individual due to the pre-test is lost by the time the measurement program begins.

As the initial strength of each wrist is known before the measurement program begins, an accurate determination can be made regarding the actual quantity of strength potentialities presupposed to be transferred to the contralateral limb.

<u>Methodology</u>. Twenty male college freshmen from Fort Hays Kansas State College were employed as subjects for this study. The subjects selected were those who could meet with the investigator during the designated daily time for the required number of days. All subjects professed to be right handed. None of the subjects were enrolled in any other formal type of measurement program during this study.

The cable tensiometer and associated equipment was utilized as the testing instrument for this study. The equipment arrangement and subject placement allowed for the isolation of the wrist flexor muscles, thus measuring only the maximal exertions of this muscle group. Adjustments were made in the length of the cable to allow each exercised wrist to remain in a state of hyper-extension throughout the entire measurement program.

Before the pre-test the height, weight, and date of birth for each subject were recorded on a data sheet. Standardized instructions were read to the individual subjects both before the pre-test and each succeeding measurement day. Following the instructions the forearm was strapped to a restraining board in a comfortable but secure position. The subjects were then tested by exerting five trials maximal, one minute apart, on the instrument. In order to facilitate a standard measurement, no subject was allowed to exercise for more than five seconds with each trial.

The mean score of the five trials for each subject was used as the daily score in the analysis of data. The t-test was used to determine whether or not a significant change occurred between the pre-test scores and the day one scores. The F test was employed to determine the day effect upon the mean exerted strength scores. When a significant F occurred, a critical difference test was given to find which days were significantly different from each other.

Results. The t-test resulted in non-significant t's occurring between the recorded mean scores of the pre-test and day one with each unilateral strength measurement program. The method employed for isometrically measuring the maximal strength of the wrist flexor muscles was concluded to be stable for the test re-test measurement program fourteen days apart.

The resulting data found only one of the four unilateral measurement programs demonstrating a significant change in its mean exerted strength scores from day one to day five. The F test found that a non-significant strength change occurred within the right hand of both groups "A" and "B" and the left hand of group "B". The left hand of group "A" demonstrated a significant change in the exerted strength scores; however, this change was a significant decrease and not an increase as anticipated. A critical difference test applied to this group found that only day one differed significantly from days two, four and five. Each of these succeeding daily mean scores was significantly lower than day one.

Conclusions. The following conclusions are presented as the basis of the resulting data obtained from this study:

1. The repeated maximal isometric measurement schedules of short duration are satisfactory in a reliability sense for measuring the maximal strength of the wrist flexor muscles in a test re-test situation fourteen days apart.

2. The repeated maximal isometric measurement schedules are not capable of eliciting significant increases in strength potentialities of the exercised muscles during a five day measurement program.

4. No transfer effects of strength potentialities to the contralateral limb resulted as the exercised muscle group itself failed to demonstrate a significant increase in exerted strength.

Recommendations. The results of this study still leave many unanswered questions in this area of strength development and cross transfer effects. Is the repeated maximal isometric type measurement program sufficient to create actual increases in strength? When indicated strength increases do occur, are these merely increases in learnings, skills, or actual muscular strength development? To what degree must the strength be increased in the exercised muscle group before a significant strength potentiality will occur within the contralateral muscle group? Thus, the results of this study warrant certain recommendations:

1. Further investigations are deemed necessary employing the pre-test and the maximal isometric strength measurement program to determine if this method is capable of eliciting strength increases.

2. Further investigations are deemed necessary employing a measurement period in excess of five consecutive days to determine the quantity of strength changes, both within the exercised muscles and the contralateral muscles.

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APPENDIX A

TABLE VI

SUMMARY OF DAILY TENSIOMETER STRENGTH MEASURES (n = 10)

GROUP "A"

Left Hand

	Day I	Day II	Day III	Day IV	Day V
Mean	46.08	44.01	44.92	43.25	44.10
Standard Deviation	6.51	4.81	5.91	5.44	5.28
High	59.8	52.9	55.9	53.8	55.1
Low	33.2	34.4	33.5	32.7	36.2
Range	26.6	18.5	22.4	21.1	18.9

Right Hand

	Day I	Day II	Day III	Day IV	Day V
Mean	47.30	46.20	46.33	46.52	46.14
Standard Deviation	4.45	4.42	4.42	4.01	5.45
High	53.3	53.4	54.3	50.4	54.4
Low	39.4	39.2	38.1	38.4	38.4
Range	13.9	14.2	16.2	12.0	16.0

APPENDIX C

TABLE VII

SUMMARY OF DAILY TENSIOMETER STRENGTH MEASURES (n = 10)

GROUP "B"

Right Hand

	Day I	Day II	Day III	Day IV	Day V
Mean	47.86	47.32	47.74	46.60	47.36
Standard Deviation	5.93	5.50	5.96	5.47	5.25
High	58.9	56.5	57.2	55.1	57.1
Low	40.8	40.7	38.9	39.3	41.1
Range	18.1	15.8	18.3	15.8	16.0

Left Hand

Mean	48.98	46.74	48.41	48.22	47.49
Standard Deviation	7.59	8.07	8.34	8.49	6.84
High	62.2	61.0	61.4	60.0	56.5
Low	39.4	37.9	36.2	34.7	36.8
Range	22.8	23.1	25.2	25.3	19.7