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An Investigation of the Effects of Autosuggested Muscle Contraction on Muscular Strength and Size.

Louis Elmo Bowers

Louisiana State University and Agricultural & Mechanical College

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A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy

in

The Department of Health, Physical, and Recreation Education

by

Louis Elmo Bowers
B.S., Southwestern Louisiana Institute, 1958
M.S., University of Maryland, 1960
May, 1964
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ABSTRACT

The purpose of this study was to investigate the effect of isotonic muscle contractions, performed by means of autosuggestion, on muscle strength and size as compared to the effects of isometric and static contractions. The "cross transfer" of strength and size development of the contralateral unexercised limb was also investigated along with the change throughout the study in measurement of muscle action potentials during autosuggested muscle contraction.

Sixty-one volunteer subjects, whose mean age was 21 years, were randomly assigned to one of four groups which included autosuggestion, isometric, and static contraction exercise groups, and a no exercise control group.

Initial measurements of elbow flexion strength of the left and right arms were made by means of a cable tensiometer with the subject seated in a specially designed chair. Forearm and biceps girth measurements of both arms and muscle action potential recordings during autosuggested contraction were also taken at the beginning of the study. All measurements were repeated after three weeks and six weeks of exercise.

Each exercise group performed five contractions of the elbow flexor muscles on three days a week for a six-week period. The isometric exercise group used an "all-out" isometric contraction held
for a 10-second duration against an immovable tensiometer cable strap. The static contraction exercise group performed five static contractions for a 15-second duration. The static contractions involved simultaneously contracting the agonistic and antagonistic muscles involved in elbow flexion. The autosuggestion exercise group performed five isotonic elbow flexion contractions by repeated self-suggestions of a positive and vivid nature to the effect that a strong muscular contraction would take place.

Simultaneous recordings of the action potentials of the biceps and triceps muscles during autosuggested muscular contractions were made and analyzed to study the effect of suggesting the lifting of a heavy weight on the force of the elbow flexion contraction and to study the role of the triceps muscle in autosuggested contraction.

An analysis of covariance was used to analyze the between group differences and further comparisons were made by utilizing a one-tailed t test and Duncan's New Multiple Range Test for unequal groups.

Based on the results of the study, the following conclusions are drawn:

1. Five autosuggested or five "all-out" isometric contractions performed three days per week for three weeks will produce significant strength increase.

2. Six weeks of training three days per week performing five isometric, static or autosuggested muscular contractions will significantly
increase strength.

3. Isometric exercise is more effective in developing strength over a six-week period than either static or autosuggested exercise.

4. There is no difference in the strength resulting from six weeks of training using a 15-second static contraction and training utilizing autosuggested muscular contraction.

5. Increase in muscle size does not result from isometric, static, or autosuggested muscular contraction as performed in this study for a six-week period.

6. No cross transfer of strength or size from the exercised to the contralateral unexercised arm occurred in this study.

7. Improvement in the force of the contraction of a muscle during autosuggested contraction as indicated by increased muscle action potential measurements occurs as a result of practice.

8. The suggestion of lifting a heavy weight used during the performance of autosuggested muscular contraction helps bring about a more forceful contraction as indicated by increased measurements of muscle action potentials.

This investigator recommends further exploration of the use of autosuggested muscular contraction in rehabilitating injured muscles involving severed nerves which have been rejoined surgically or in paralysis resulting from degenerated peripheral nerves.
CHAPTER I

INTRODUCTION

Physiologists have repeatedly verified the commonplace observation that muscles increase in size as a result of regular periods of heavy physical exercise. Increases in muscle size usually accompany strength increases although the strength increments are usually proportionately greater than the increases in muscle girth. Karpovich stated that the increase in size and strength of muscles which accompanies training is largely due to the fact that there are latent or unused muscle fibers that are atrophied from lack of use, and these small muscle fibers respond to the increased demands put upon the muscle. The exercising of the normally unused muscle fibers causes them to become larger, thus increasing the over-all strength of the muscle.

The most frequently used method of strength development today, progressive resistance exercise with weights, employs this theory of exercising unused muscle fibers. It is thought that more of the normally unused muscle fibers are forced to contract by increasing the

1Peter V. Karpovich, Physiology of Muscular Activity, (Philadelphia: Saunders and Co., 1953), p. 28.
resistance encountered by the muscle during contraction.

In isometric strength building exercises, the resistance opposing the muscular contraction is the maximum since the resistance is immovable. In this type of exercise an effort is made to contract the muscle to its fullest in an attempt to bring into use as many muscle fibers as possible.

It is known that, accompanying the hypertrophy of muscles due to exercise, chemical changes occur in the muscle tissue; but the question as to whether the stimulus for the hypertrophy of the muscle is the mechanical involvement of tension and pressure or a chemical phenomenon is not yet clear. This investigator suggests the possibility of the stimulus being psycho-chemical in nature.

Although muscle strength is ultimately the result of the physiological cross section of the muscle and the physiological state of its tissues, the psychological factors which affect the individual's volitional muscle strength should not be overlooked. Observations reported in a recent study by Ikai and Steinhaus support the thesis that the expression of human strength is generally limited by psychologically induced inhibitions.

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Morehouse stated that "...it is probable that an individual in an untrained state possesses all of the physical requisites present in a trained state. What the individual acquires during training may be an increased ability to overcome the innate protective governor-inhibition." An exercise which would reduce these inhibitions would possibly increase volitional muscle strength.

This writer proposes the possibility of increasing muscle strength and size by means of autosuggested muscular contractions. In the autosuggestion system of exercising developed by the investigator, isotonic muscular contraction is brought about through repeated suggestions of a vivid and positive nature to oneself that muscular contraction will occur. During the autosuggested contraction, the individual is in a relaxed state of deep concentration and does not enter a trance. After initiating muscular contraction through self suggestion, the individual further suggests to himself that the muscle is contracting against a very heavy weight. The effect of the suggested heavy weight necessitates a stronger autosuggested contraction to overcome the "suggested resistance". Probably, the resistance provided by the autosuggested heavy weight comes from the contraction of antagonistic  

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muscles. It is conceivable that it would be possible to build muscle size and strength by stimulating many motor units through autosuggestion which would subsequently contract muscle fibers, thus bringing about the physical and chemical changes in the muscle which occur in muscular contraction against an external resistance without an actual external resistance being present.

Further, this experimenter has found that electromyographic muscle action potentials are present and are of sufficient magnitude in autosuggested muscular contraction to be recorded on an electromyographic instrument. Studies by Lippold; Bigland and Lippold; and Liberson, Dondey, and Asa revealed an essentially linear relationship between the sum of electrical activity of a muscle and the mechanical force exerted by the muscle in voluntary contraction and, in the absence of

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4 Electromyographic measures were made of a subject while performing autosuggested contraction of a muscle during a demonstration of the Physiograph presented for this investigator at the University of Southwestern Louisiana on November 28, 1962 by Mr. Charles Cunningham of the E&M Instrument Company of Houston, Texas.


fatigue, the integrated electromyographic recording is proportional to the number of motor units and, to a lesser extent, to frequency of their discharges. Loofbourrow stated that "...although the EMG (electromyograph) is only an indirect measure of contraction in physiological conditions, EMG amplitude and the mechanical response are essentially parallel". The questions are then raised as to whether magnitude of muscle action potential measures during autosuggested muscle contraction would be affected by a program of autosuggested contraction and would the exercises contribute to an increase in muscle strength.

I. STATEMENT OF THE PROBLEM

The purpose of the study was to investigate the effect of autosuggested muscular contraction on the development of muscle strength and size. The study involved a control group and three exercise groups, one performing autosuggestion contractions, one isometric contractions, and one static exercises. The effect of each of the three exercises performed in the study on the strength and size of the bilateral unexercised arm was also investigated.

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More specifically the objectives of the study were:

1. To investigate the effects of autosuggested, isometric, and static contraction of the elbow flexor muscles on elbow flexion strength and forearm and biceps girth size.

2. To explore the effects of unilateral training of the preferred arm by means of autosuggested, isometric, and static muscle contractions on the development of strength and size of the unexercised arm.

3. To compare changes of measures of muscle action potentials of the biceps brachii muscle of the arm during the performance of autosuggested muscle contraction after three weeks and six weeks of training.

4. To study by means of action potential measures the role of the suggested heavy weight and of the triceps muscle in autosuggested elbow flexion.

II. SIGNIFICANCE OF THE STUDY

To the best of this writer's knowledge, this was the first study designed to explore the use of autosuggested muscular contraction as a means of increasing muscle strength and size. The study of action potentials during autosuggested contraction along with subsequent studies in this area will possibly contribute to a better understanding
of the psychological and physiological functions which occur during muscular contraction and muscle strength development.

It is suggested that this technique of muscular exercise could have application in the area of muscle rehabilitation where the muscles of immobilized limbs could be contracted by autosuggestion in order to prevent atrophy. Information obtained from this study may stimulate further investigation of the use of autosuggested exercises in the re-education of muscles in cases of injury or paralysis.

Development of autosuggested type exercises may also provide a convenient and inexpensive means of increasing muscle strength, which would have uses in physical education classes, the military, and even in space travel.

III. DEFINITION OF TERMS

Definitions of terms as they were used in this study are presented below:

**Autosuggested Exercise.** Autosuggestion is commonly associated with a trance; however, in this study the subjects were in a conscious state of deep concentration. An operational definition of autosuggested exercise as used in this study is, therefore, an isotonic contraction of the muscles about the elbow initiated and performed by repeated suggestions of a positive and vivid nature to oneself to the effect that strong muscular contraction will take place. The autosuggested contraction exercise further employs the use of a suggestion that a
very heavy weight is being lifted in order to facilitate bringing about a stronger autosuggested muscle contraction to overcome the resistance.

**Isometric Exercise.** An attempted elbow flexion against an immovable resistance (a strap over the wrist) in which no shortening of muscle fibers takes place.

**Static Exercise.** A contraction of the elbow flexor muscles in which no shortening of muscle fibers occurs due to the resistance offered by the simultaneous contraction of the antagonistic muscles.

**Muscle Action Potential.** A measure of the electrical potential change of the cell membrane of the muscle during voluntary contraction from that of the resting membrane potential. This variation in membrane potential in which the interior becomes positively charged with respect to the exterior is accomplished by trading sodium for potassium ions across the cell membrane.  

**Physiograph.** An instrument which graphically records muscle action potentials measured by means of external electrodes.

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CHAPTER II

REVIEW OF LITERATURE

A survey of the literature revealed that there were no studies dealing with the effect of autosuggested muscular contraction on muscle strength or size. Related studies were found in which muscle action potentials were measured while subjects imagined lifting weights and in which the effects of hypnotic suggestion on physical performance were investigated. The above studies, along with research which studies the use of isometric and static type exercises in the development of arm strength and studies which investigated the transfer of strength from the exercised to the non-exercised limb, are presented in this chapter.

I. STUDIES RELATED TO AUTOSUGGESTION

Suggestion is commonly employed in many areas of modern society. The subtle suggestion of a television commercial, the indirect suggestion communicated from the parent to the child, or the direct suggestion employed in self hypnosis differ only in degree or strength.
In their book, *Hypnotism Today*, Lecron and Bordeaux explained that the phenomenon of autosuggestion has been recognized since the earliest days of hypnotic history; however, it was not well known until the second decade of the nineteenth century. Emile Coue brought it into world prominence when he used his autosuggestion method, in which no trance state was present, in treating the ill. The New Nancy School as Coue called his system, attracted thousands from France and Europe who came to learn autosuggestion to cure themselves of ailments. The Coue system no longer has a large following and since autosuggestion has had no controlled scientific investigation, its actual worth is not clearly known.

In *The Practice of Autosuggestion by the Coue Method* Brooks stated, "In suggested arm movements the unconscious automatically realizes your thoughts through the nerves and muscles of the arms and hands."

Jacobson, who developed the progressive relaxation technique, conducted a study dealing with the electro-physiology of mental activities

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which involved the measurement of muscle action potentials while imagining the lifting of weights. He found that during imagination or recollection of muscular acts contraction occurs in some of the muscle fibers which would engage in the actual performance of the act. He further concluded that the detection of action potentials in muscles always signifies the presence of shortened muscle fibers.

Shaw, who was interested in the study of mental activity through the measurement of action potentials of muscles, conducted a study involving three subjects trained in relaxation in which he measured muscle action potentials during imagined weight lifting. He had the subjects actually lift weights of various magnitudes and then had them imagine they were lifting the various size weights while remaining still and completely relaxed. During both the actual and imagined weight lifting he measured the muscle action potentials present in the muscles which would normally be involved in the lifting of the weights. From the study he concluded that during imaginal lifting of a weight muscular activity occurs, as measured by amplified muscle action potentials of the forearm. He also concluded that the amount of muscular activity increased during imagining as well as during actual lifting with the magnitude of the weight, with the relationship being linear in both cases. He further stated that the greater the vividness of the imaginal lifting

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as reported by each subject, the greater the amount of muscular activity. There was some evidence that the higher degrees of vividness were reported more often during imaginal lifting of the heavier weights in the series.

At the colloquium on Exercise and Fitness in 1959, Morehouse reported a study concerning the contribution of cerebration to strength performance. The study conducted by Egstrom in the University of California laboratory involved eleven subjects who thought about exerting maximal flexion effort for a ten-second duration three times a week for four weeks. Eight subjects who performed no exercise during the four week period served as a control group. He found the strength gain of the experimental group to be not significant above that of the control group. Egstrom stated in a personal communique to this investigator that the results of three studies which he conducted concerning the effect of cerebration on strength increase were not consistent, and although some individuals demonstrated rather startling changes, the between group differences in each study were not significant.

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6 Glen W. Egstrom, As expressed in a letter to this investigator, May 8, 1962.
A pilot study was conducted by this experimenter in which the effects of exercises involving autosuggested muscle contraction on elbow flexion strength and arm girth size were investigated. Seven male subjects performed five autosuggested elbow flexions with an imagined heavy weight in the hand three times per week for ten training periods. The dominant arm of each subject exercised by means of autosuggestion and his non-dominant arm remained idle. The subjects refrained from all other strength building types of activity for the duration of the study. In addition a partial control group of eight subjects engaged in wrestling were used in the study. Elbow flexion strength tests of both the right and left arms were administered at the beginning and end of the ten training sessions. The mean elbow flexion strength gain of the exercised dominant arm of 12.2 pounds was significant at the five per cent level. The mean increase in strength of the idle non-dominant arm was 6.7 which was significant at the five per cent level. No significant increase in either biceps or forearm girth size for either the right or left arm was found. The mean elbow flexion strength increase of the subjects participating in the wrestling group was six pounds for the right arm and eight pounds.

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for the left arm. The strength gains achieved by the wrestling group followed a uniform pattern among individuals for both the right and left arms; whereas the strength gains found in the autosuggestion group were irregular. During the performance of autosuggested muscle contractions, physiological measurements showed an increase in heart rate, respiration rate, and temporary swelling of the biceps muscle presumably due to increased flow of blood and lymph in the area.

Although there is a distinction between autosuggestion in the waking state and either hypnosis or auto-hypnosis, all three methods employ the principles of positive suggestion. The studies to follow in this section will deal with the effects of hypnotic and posthypnotic suggestion on physical performance.

A study by Johnson reported the effect of posthypnotic suggestions on all out effort of a short duration on a bicycle ergometer. Ten male subjects in excellent physical condition were trained in hypnosis, (including complete post-hypnotic amnesia) and were tested twice on the bicycle ergometer (26.8 pounds resistance) on all-out rides of 100 revolutions. The subjects were placed in a trance before both test

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rides and were given posthypnotic amnesia which prevented them from consciously recalling what took place in the trance. Before one of the test rides they were given posthypnotic suggestions to the effect that they would have unusual strength, endurance, decreased sensitivity to pain, and would recover rapidly from the effort.

The mean performance after suggestions did not differ significantly from the mean performance without suggestions. Although the subjects were not consciously aware that suggestions had been given, their subjective reactions as to how they felt after their rides were consistently more favorable when hypnotic suggestions were given.

Johnson further reported an investigation of the effects of various hypnotic and posthypnotic suggestions on performing a bench press with a barbell. Ten young men in excellent physical condition were trained in hypnosis to meet the criteria of the study which included the ability to experience vivid visual and auditory hallucinations, to move about skillfully and naturally in the trance state, to carry out posthypnotic suggestions, and to undergo spontaneous posthypnotic amnesia. The subjects performed a bench press with a 47 pound barbell at a set cadence. Each subject performed after receiving

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hypnotic suggestions in four different conditions: (A) stereotyped suggestions in trance, performance in hypnotic trance; (B) pep-talk suggestions (urgent but not hysterical) in trance, performance in hypnotic trance; (C) suggestions in the trance to be activated post-hypnotically by a signal during exercise; and (D) posthypnotic failure suggestions to reduce performance out of hypnosis. There was no conscious awareness on the part of the subjects of any suggestions being given to them under any of the four conditions.

Statistical analysis of the data revealed no significant differences among conditions A, B, and C, but a very significant difference between condition D (posthypnotic failure suggestions) and the others.

Subjects were puzzled and somewhat upset by their poor performance in condition D. They could not account for their performance and rationalized it on the basis of being sure that the barbell was heavier than usual, or for some reason they had a bad day.

Ikai and Steinhaus reported significant mean increases in elbow flexion strength in seven subjects of 18.3 lbs. due to suggestions under hypnosis and 15.5 lbs. in the state of posthypnotic suggestion. They found posthypnotic suggestions of weakness and pain significantly reduced the average strength of the group nearly 22 lbs. below their prehypnotic controls. There was a persistence of the increased

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10 Ikai, loc. cit.
strength of the group in the terminal waking state, but at a somewhat reduced level, i.e. 12.9 lbs. mean gain above the post-study strength scores. Ikai and Steinhaus state:

Thus suggestions that the subject's power is increasing, that he can pull like never before without feeling an ache or pain, etc. must in some way reinforce or integrate the positive and inhibit the traces of earlier negative experiences in whatever portion of the cortex these may reside, so that the resulting pull approximates a completely freed, disinhibited expression of the brain's power over the musculature.

II. ISOMETRIC AND STATIC EXERCISE STUDIES

Since the Hettinger and Mueller study in 1953 which reported a weekly strength increase of 5 per cent resulting from a single isometric contraction per day of two-thirds strength held for six seconds for a period of ten weeks, many investigations of the effect of isometric muscular contractions have been undertaken. Since completed reviews of isometric type studies are readily available and because the main purpose of this study concerned autosuggested muscular contraction only a review of isometric and static studies involving changes in arm strength and size will be included here.

11 Ibid., pp. 159 - 160.
The purpose of a study by Wolber and Sills was to determine whether static muscle contractions would result in significant changes in strength. Two groups of students from the laboratory school of the State University of Iowa were administered four tests of strength at the beginning and at the end of an eight-week period. The experimental group (performing static muscular contractions) made statistically significant gains in strength on the back lift and combined hand grip strength tests than did the control group. The authors concluded that static muscle contractions will cause significant gains in strength.

Mathews and Kruse compared the results of isometric and isotonic type exercises on elbow flexion strength over a four week period. One hundred and twenty male college students were equated into eight groups, with four groups in each exercise unit, on the bases of their elbow flexion strength scores. The respective groups exercised two, three, four, and five times a week over a period of four weeks.

The results obtained in the study were:

1. No common regression line was found in the eight groups, indicating the strength changes were peculiar to the indi-

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individual, regardless of exercise frequency.

2. The isometric type exercise caused a greater number of subjects to significantly gain in strength.

3. The five-day-a-week exercise program was most beneficial in terms of strength gains.

An apparent weakness in the above study is that subjects in the isotonic exercise group performed one isometric contraction of maximal effort on the Clarke tensiometer with each visit to the laboratory in order to determine their strength so that a weight load of 3/16 of their maximum strength could be placed on the ergograph. The authors include this as part of their procedure but seemingly do not consider it in drawing their conclusions.

Rarick conducted a study in which the effectiveness of a single daily six second exercise bout employing two-thirds maximum tension was compared with an exercise program involving more frequent exercise bouts at 80 per cent maximum tension. Thirty post-pubescent boys divided into one control group and two experimental groups served as subjects. Each experimental group underwent a four week training program restricted to isometric contraction of the wrist muscles, with the programs differing only in regard to the frequency of the exercise

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bouts and the levels of static muscular tension utilized. The results
generally supported the findings of Hettinger and Mueller, in that
brief periods of isometric tension (one six-second bout daily at two-
thirds tension) proved to be as effective for strength development
as more frequently repeated exercise bouts at high levels of tension.

The results of a study by Adamson indicated that a training
program of isometric exercise using two-thirds maximal tension held
for six seconds once daily was not as effective in developing grip,
elbow flexor and spine extensor strength of 20 year old university
males as a program including repeated isotonic exercise involving
circuit training and weight training.

Adamson later compared the responses of two groups of English
schoolboys to higher tension and more frequently repeated isometric
and isotonic exercise bouts than those used in his earlier studies of
university students.

The study included two experimental isometric and isotonic groups

16 Hettinger, op. cit., p. 111.

17 G. T. Adamson, "Milo or Mueller," Journal of Physical Educa-
tion Association of Great Britain and Northern Ireland, L 1, 1959,
1159. as found in G. T. Adamson, "Effects of Isometric and Isotonic
Exercise on Elbow Flexor and Spine Extensor Muscle Groups,"
Health and Fitness in the Modern World, (Chicago: The Athletic

18 G. T. Adamson, "Effects of Isometric and Isotonic Exercise on
Elbow Flexor and Spine Extensor Muscle Groups," Health and Fitness
in the Modern World, (Chicago: The Athletic Institute, 1961),
p. 172 - 180.
and one control group drawn from 25 boys whose mean age was 11.5 years. Maximal strength tests were given to all subjects three days before the experimental period and four weeks later after 20 training sessions. Total strength scores included the results of six maximal contractions on each dynamometer at ten second intervals. Equating of groups was made on the basis of the subjects' elbow flexion and back extensor strength tests and body weight ratios.

Strength training for the isometric group consisted of six maximal pulls at 10 second intervals 5 days per week on both a spring dynamometer designed for a two handed elbow flexion exercise and on a hydraulic back dynamometer adjusted for a back extension exercise. The isotonic group performed six repetitions of two exercises, the barbell curl and high pull-over using a disc loaded barbell.

The results showed a mean increase of 10 lbs. in elbow flexion strength for the isometric group, an isotonic group mean increase of 6.67 lbs. and a control group mean increase of 2.5 lbs. The writer concluded that substantial gains in static elbow flexion and back extensor strength were obtained over a four week period of training from both a brief isometric program and also from a daily isotonic schedule.

Berger made a study in which he compared the effects of static training and various dynamic training programs on strength development.

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The investigation involved fifty-seven male college students who were trained statically three times weekly, for 12 weeks. The static exercise involved maintaining a 6-8 second maximum contraction in two positions of the bench press lift, the first with the barbell at the chest and the second with the arms flexed at 90 degrees. Strength before and after training was measured by totalling the maximum weight lifted in the two exercise positions of the bench press. The strength increases of the statically trained group was compared to the improvements made by nine groups of subjects who trained dynamically with various bouts and repetitions for the same length of time.

An analysis of covariance showed that the statically trained group was significantly different in strength improvement from seven of the nine weight training groups. The weight training group that trained dynamically for three bouts and six repetitions per bout exceeded the static group in improvement and the group that exercised dynamically for two bouts and two repetitions per bout was inferior to the static group. Berger concluded that the advantage of static training is that a great number of exercises can be performed five and six days a week for extended periods of time without undue fatigue.

In a recent study Bergeron found that a six second maximum

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isometric contraction three times a week for ten weeks produced significant increases in both the strength and size of the muscle. Of pertinence to the present study is the finding by Bergeron of a significant increase in the strength and size of the arms as a result of an isometric supine press exercise.

III. CROSS TRANSFER STUDIES

Since the initial study by Wissler and Richardson in 1900 which reported that exercising one arm improved the muscular performance in the muscles of the unexercised arm many studies have investigated this phenomena. Observed muscular contraction in the unexercised arm in this original study was attributed to the diffusion of motor impulses spreading from the exercised to the nonexercised arm.

Davis later gave considerable support to the theory that the cross transfer of strength to the contralateral arm is due to "cross exercise". This study showed that simple voluntary movement in one limb is accompanied by muscular activity in all four limbs and

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although the activity in the remote limb is much less than that of the moving limb, it is nevertheless substantial.

In 1947 Hellebrandt, Parrish and Houtz using heavy unilateral resistance exercises were able to demonstrate an increase of strength in the symmetric unexercised contralateral muscles. In their opinion the cross exercise effect was found to depend primarily upon the severity of the exercise rather than on the duration.

Slater-Hammel employed twenty male college students in a study to test the bilateral effects of systematic exercise. Ten students served as controls and received no special exercise.

The evidence obtained showed that systematically exercising one arm results in a positive and significant improvement in the muscular performance (repetited arm flexions with a 14 pound weight) of the other arm. Two weeks after the exercise period the experimental group lost their superiority over the control group in their left arm performance.

The author suggested that the bilateral effects were due simply to a raising of the subjects' tolerance to fatigue sensations or a transfer

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of motor coordination. The fact that bilateral gains were rapidly lost after the cessation of exercise suggests however that the gains were primarily physiological.

The purpose of a study by Hellebrandt in 1951 was to measure the bilateral influence of the unilateral practice of standardized activities requiring manual dexterity and to determine whether the non-preferred hand gains more from practice of the dominant side than vice versa.

The study involved 50 adult subjects who practiced four tests of tracing, tapping, copying, and dotting. The group was divided into two groups of matching degrees of handedness based on the subjects' dextrality quotient. One group practiced with the left hand and one with the right hand.

Statistical analysis of the initial measurement of performance of the right and left sides and those administered at the termination of the experiment supported the following conclusions:

(1) Manual dexterity improves significantly with direct practice.

(2) In general the mechanical ability of the dominant limb improves more with direct practice than that of the contralateral extremity.

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(3) The unpracticed contralateral extremity also improves significantly in mechanical ability.

(4) Dextral improvement due to cross education does not approach that achieved by direct practice.

(5) The non-preferred side may gain more as a result of practice by the contralateral limb than by ipsilateral direct practice, but the differences are not significant.

Mathews compared the effects of exercising the elbow flexor muscles by means of isotonic and isometric contractions of one arm upon strength and endurance of similar muscles of the other arm. The results showed there was a significant gain in strength in both the exercised and unexercised muscle groups; however significant increases in muscular endurance were found only in the exercised muscle group.

Rasch and Morehouse reported a study designed to investigate functional relationship between hypertrophy and strength, the effects of exercise on contralateral muscles, the persistence of strength gains, and the specificity factor in testing strength.

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The effects of a six-week program of isotonic and isometric exercises involving elbow flexions and elevations of the arm were observed in 49 male subjects. Initial measurements of the girth of the biceps were made followed by elbow flexion and arm elevation strength tests administered with a strain gauge dynamometer with the subjects in a standing position. Subjects were then tested in a lying position in which strength could be measured, but one in which he did not exercise during the training period. In addition subjects were tested on a modification of the Martin test to determine the effect on strength when the method of testing was changed to one which was not practiced during the training period.

Isotonic exercises consisted of progressive resistance exercises, with the resistance furnished by plate-loading dumbbells. Three sets of five elbow flexions and five arm elevations with maximum resistance were performed three times per week. The isometric group training consisted of three elbow flexions and arm elevations in which the subject exerted and maintained for 15 seconds an isometric contraction equal to two-thirds of maximum strength. At the end of the training period the strength tests were readministered and after the subjects had refrained from exercise for a period of six weeks the tests were again repeated.

The results showed the mean elbow flexion strength increase in the isotonic group to be a significant 14 lbs. in the exercised arm and
11 lbs. in the unpracticed contralateral arm. In the isometric group, there were no significant changes in strength in either the exercised arm or in the unpracticed contralateral limb. During the rest period there was a significant mean increase of 1.9 lbs. in the strength of the unpracticed contralateral arm in the isotonic group, but no significant change in strength in the exercised arm was recorded. In the isometric group the exercised arm showed nonsignificant losses after the rest period. A significant mean increase of 25 lbs. in arm elevation strength in the exercised arm and 24 lbs. in the unpracticed contralateral arm was found to exist in the isotonic group. The isometric group showed a significant mean increase of 12.8 lbs. in arm elevation strength in the exercised arm and a nonsignificant mean increase of 7.9 lbs. in the contralateral arm. Tests after a six week rest period revealed no significant change in the isotonic group mean strength; however the mean strength of the isometric group decreased significantly by 11.6 lbs. in the exercised arm, but no significant change was noted in the unexercised arm.

The strength increases resulting from isotonic training were considerably larger when the subject was tested in the position in which he performed the exercises than when tested in a position or by a technique unfamiliar to him. The investigators felt that this suggests that these increases may have been largely the result of learning rather than actual increases in muscular contractility and that it does
not seem likely that cross transfer of strength to the unpracticed contralateral limb would take place if it were dependent upon actual changes in contractile strength.

In a study by Gregg, Mastellone and Gersten electromyographic tracings were made of 20 healthy adult subjects to study the "cross exercise" effect of resistive exercise. Electromyographic recordings were obtained from the biceps brachii muscles of the exercised arm and the unexercised contralateral arm during flexion and extension of the elbow.

The authors presented the following conclusions based on the results of the study:

1. Overflow to the unexercised, contralateral muscles did not occur during simple, non resistive exercise, or during isometric contraction of the bicep brachii.

2. Overflow invariably appeared first in the opposite triceps brachii. Overflow to the biceps appeared as the exercise stress increased.

3. Positioning of the unexercised arm and stabilizing the body with straps did not influence the appearance or distribution of the overflow.

4. A relationship between the appearance of overflow, movement of a heavy load, and fatigue is suggested.

Sills and Olson recorded the electrical activity in the unexercised arm when the opposite arm was exercised. Seventeen subjects exercised the dominant arm by raising it to a 45 degree angle as four and one-half pound weights were systematically added until the subject could no longer perform the exercise. It was found in the study that the microvoltage in the unexercised arm increased as the resistance in the exercised arm increased. On an average 70 percent of maximum strength produced an action potential reading of 10 microvolts in the unexercised arm and maximum contractions elicited, on an average 30.4 microvolts in the unexercised arm. The authors concluded that either static muscle setting or active exercise will elicit higher electrical potentials in an arm than will exercising the opposite arm against maximum resistance.

A study by Walters, Steward, and LeClaire investigated the effects of isotonic and isometric muscular contraction on the elbow.

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flexion strength and endurance of the exercised and nonexercised arms. Fifteen subjects were divided into three experimental groups equated in terms of the strength of the elbow flexors of the preferred arm. One group trained exerting a full isometric contraction each day, the second group contracted two-thirds its full isometric tension, and the third group lifted one-third of its one lift maximum as fast as possible for a 45 second period. All groups were tested before and after the eight week exercise period for strength in the preferred and non-preferred arms and in the number of times they could lift a load which was one-third of their one lift maximum. The authors concluded that all of the three training methods employed in the study were effective in the development of strength, but the full isometric method was superior to the two-thirds method in developing strength. An improvement in the strength of the non-preferred arm was produced by all of the exercise methods used in the study.

Panin performed electromyographic studies of muscles in the upper and lower extremities in order to evaluate the effect of exercise of one muscle upon non-exercised muscles. The greatest electromyographic activity as measured by surface electrodes was found in the exercised muscle. Action potentials of low amplitude and low frequency were found in all non-exercised muscles studied. Action

potentials were not limited to the contralateral but were wide spread throughout all four extremities. The electrical activity appeared to be greatest in those muscles required to stabilize the body while performing the exercise. At no time were the electromyographic potentials in the non-exercised muscles greater than 20 per cent of the amplitude of potentials in the exercised muscle which the authors concluded were insufficient to constitute exercise effect.

In a study by Schweid brief maximal isometric quadricep exercises performed 5 days per week for 8 weeks by 48 third grade children produced a significant increase in knee extensor strength without measurable hypertrophy. The quadriceps strength in the unexercised leg of the experimental group as well as the legs of subjects in a separate control group exhibited no significant gains in strength.

Gardner in a study concerned with the specificity of knee extension strength along the range of motion when the limb was exercised by means of isometric exercise at only one point included in the range, also investigated the extent to which strength scores might be changed specifically on the non-exercised limb. Sixty subjects equated into


four groups trained for a six week period, employing a two-thirds maximum six-second isometric contraction. The results showed all exercise groups improved significantly in strength of the exercised limb, but there was no significant improvement for the non-exercised limb.

IV. SUMMARY OF RELATED LITERATURE

Studies Related to Autosuggestion.

A survey of the literature revealed that the term autosuggestion has been known since the earliest days of hypnotic history; however, no studies were found which utilized autosuggestion to bring about contraction of muscles as a possible means of developing strength.  

In a study of the electro-physiology of mental activities, Jacobson found that during the imagination of the lifting of weights, increased action potentials occurred in the muscle fibers which engaged in the actual performance of the act. Shaw further substantiated these findings and showed that the amount of muscular activity during imagining, as measured by amplified muscle action potentials of the forearm, increased with the magnitude of the weight being imagined.

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34 Lecron and Bordeaux, loc. cit.

35 Jacobson, loc. cit.

36 Shaw, loc. cit.
Egstrom's study revealed no significant strength gain in eleven subjects who thought about exerting maximal flexion effort for a ten-second duration three times a week for four weeks.

An exploratory study by this investigator in which seven subjects were used showed a significant increase in elbow flexion strength of the dominant arm as a result of five autosuggested elbow flexions with an imagined heavy weight in the hand three times per week for ten training periods.

An investigation by Johnson reported that posthypnotic suggestion, to the effect that subjects would have unusual strength and endurance, decreased sensitivity to pain, and rapid recovery from the effort, had no effect on an all out effort of a short duration on a bicycle ergometer. Johnson reported a study in which three types of hypnotic and posthypnotic suggestions to increase performance of a bench press with a barbell and a fourth posthypnotic failure suggestion to reduce performance out of hypnosis were used. Only the failure suggestions significantly changed performance.

However, a recent study by Ikai and Steinhaus showed a significant

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37Egstrom, loc. cit. 38Bowers, loc. cit.
40Johnson, Massey, and Kramer, loc. cit.
41Ikai and Steinhaus, loc. cit.
mean increase in elbow flexion strength in seven subjects of 18.3 lbs. due to suggestions under hypnosis and 15.5 lbs. in the state of post-hypnotic suggestion. Posthypnotic suggestions of weakness and pain significantly reduced the average strength of the group nearly 22 lbs. below their prehypnotic controls. Increased strength of the group persisted in the terminal waking state, but at a somewhat reduced level.

Studies Related to Isometric and Static Exercises.

In 1953 Hettinger and Mueller reported a weekly strength increase of 5 per cent resulting from a single isometric contraction per day of two-thirds strength held for six seconds for a period of ten weeks.

Subsequent studies of the effect of isometric exercises on muscle strength generally support the findings of Hettinger and Mueller although there is some disagreement concerning the strength of the isometric contraction needed for maximum strength development.

An examination of the studies reviewed concerning the effect of isometric and/or static exercises on elbow flexion strength reveal studies by Wolbers and Sills, Mathews and Kruse, and Berger which

42 Hettinger and Mueller, loc. cit.

43 Wolbers and Sills, loc. cit.

44 Mathews and Kruse, loc. cit.

45 Berger, loc. cit.
found significant increase in strength due to isometric type contraction exercises.

Rarick and Larsen concluded that brief periods of isometric tension (one six-second bout daily at two-thirds maximum tension) proved to be as effective for strength development as more frequently repeated exercise bouts at high levels of tension.

In a study by Walters, Steward, and LeClaire the authors concluded that the full isometric contraction method was superior to the two-thirds contraction method in developing strength of the elbow flexor muscles.

Rasch and Morehouse reported no significant change in elbow flexion strength as a result of six weeks of exercising three times per week using three isometric contractions equal to two-thirds of maximum strength.

The results of a study by Adamson indicated that a training program of repeated isotonic exercise was more effective in developing grip, elbow flexor and spine extensor strength of 20 year old university males than a program of isometric exercise using two-thirds maximal tension.

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46 Rarick and Larsen, loc. cit.
47 Walters, Steward, and LeClaire, loc. cit.
48 Rasch and Morehouse, loc. cit.
49 Adamson, loc. cit.
held once daily for six seconds. However Adamson later compared the responses of two groups of English schoolboys to higher tension and more frequently repeated isometric and isotonic exercise bouts than those used in his earlier study. He found a significant elbow flexion strength mean increase of 10 lbs. for the isometric group, and an isotonic group mean increase of 6.67 lbs.

A study by Mathews, Shay, Godin, and Hogdon resulted in significant elbow flexion strength increases through the use of isometric contraction exercises.

A recent study by Bergeron showed that a six second maximum isometric contraction three times a week for ten weeks produced significant increases in both the strength and size of the muscles of the arm.

Studies Related to Cross Transfer of Strength.

Since 1900 when Wissler and Richardson reported that exercising one arm improved the muscular performance of the unexercised arm, many studies have investigated this phenomena.

50 Adamson, loc. cit.
51 Mathews, loc. cit.
52 Bergeron, loc. cit.
53 Wissler and Richardson, loc. cit.
Davis gave considerable support to the "cross exercise" theory when he showed that simple voluntary movement in one limb is accompanied by muscular activity in all four limbs.

Hellebrandt, Parrish and Houtz using heavy unilateral resistance exercises were able to demonstrate an increase of strength in the symmetric unexercised contralateral muscles. They felt the cross exercise effect was dependent primarily upon the severity of the exercise rather than on the duration.

A study by Slater-Hammel showed that systematically exercising one arm results in a positive and significant improvement in the muscular performance (repetited arm flexions with a 14 pound weight) of the other arm.

Hellebrandt concluded that manual dexterity of the unpracticed contralateral limb improved significantly through unilateral practice, but it does not approach that achieved by direct practice.

Mathews, Shay, Godin, and Hogdon found significant gains in strength in both the exercised and unexercised elbow flexor muscle groups; however, significant increase in endurance was found only in

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54 Davis, loc. cit. 55 Hellebrandt, Parrish, and Houtz, loc. cit.
56 Slater-Hammel, loc. cit. 57 Hellebrandt, loc. cit.
58 Mathews, Shay, Godin, and Hogdon, loc. cit.
the exercised muscle group.

Rasch and Morehouse\(^{59}\) reported no significant changes in strength in either the exercised or in the unpracticed contralateral limb as a result of six weeks of isometric exercise.

Gregg, Mastellone, and Gersten\(^{60}\) utilizing electromyographic recordings of the biceps brachii of the exercised arm and contralateral unexercised arm found that overflow to the unexercised, contralateral muscles did not occur during simple non resistive exercise or during isometric contraction of the biceps brachii.

Sills and Olson\(^{61}\) concluded that either static muscle setting or active exercise will elicit higher electrical potentials in an arm than will exercising the opposite arm against maximum resistance.

Walters, Steward, and LeClaire\(^{62}\) reported that an improvement in the strength of the non-exercised arm was produced by either a two-thirds or full isometric contraction exercise.

Panin, Lindenauer, Weiss, and Ebel\(^{63}\) found that at no time were the electromyographic potentials in the non-exercised muscles greater than twenty per cent of the amplitude of the potentials in the exercised muscle group.

\(^{59}\)Rasch and Morehouse, loc. cit.

\(^{60}\)Gregg, Mastellone, and Gersten, loc. cit.

\(^{61}\)Sills and Olson, loc. cit.

\(^{62}\)Walters, Steward, and LeClaire, loc. cit.

\(^{63}\)Panin, Lindenauer, Weiss, and Ebel, loc. cit.
muscle which it was concluded were insufficient to constitute exercise effect.

Schweid recently reported that no significant increase in the quadriceps strength of the unexercised leg resulted from brief maximal isometric exercises performed five days a week for eight weeks.

Gardner reported finding no significant improvement in the knee extension strength of the unexercised limb as a result of isometric contraction.

64 Schweid, loc. cit. 65 Gardner, loc. cit.
CHAPTER III

DESCRIPTION OF PROCEDURE

The study was conducted in the Health and Physical Education Department of the University of Southwestern Louisiana in the spring of 1963 from March 25th to May 25th. Eighty volunteer subjects were randomly assigned to one of four groups. The twenty subjects in Group A (Autosuggestion Group) were designated to perform five auto-suggested elbow flexion contractions three times per week for a six week period. Subjects in Group B (Isometric Exercise Group) performed five ten second "all out" isometric contractions of the elbow flexors three times per week for six weeks. Group C (Static Contraction Group) performed contractions three times per week for six weeks. Group D (Control Group) took part in no exercise during the six week period. All groups performed the exercises with the preferred arm while the non-preferred arm was inactive. Measurement of elbow flexion strength and forearm and biceps girth size of both the preferred and nonpreferred arms were made at the beginning of the study, after three weeks of exercise and after six weeks of training. Comparison of the significance of between group differences was made by means of an analysis of covariance.
I. SELECTION OF SUBJECTS

Subjects for the study were selected from a list of male students who were formerly enrolled in the writer's physical education activity classes at the University of Southwestern Louisiana. Letters of invitation to take part in the research study were sent to 158 male students known to be enrolled in the university at the time of this study and who had completed their physical education requirements. The letter (See Appendix A) explained the approximate amount of time to be required of participants and directed them to contact the author if interested. Those who volunteered were personally interviewed by the investigator before being accepted for the study. In order to participate the students agreed to refrain from any form of exercise except that normally required to function as a student for the six weeks duration of the study. Subjects in the exercise group were also expected to report three times per week for six weeks for exercises. Students who held part time jobs which involved manual labor were excluded from the study. Of the 102 students who reported for an interview, 80 were accepted for the study. Such factors as illness, resigning from school, and failing to refrain from outside exercise, further reduced the number of subjects who completed the study to 61. The subjects ranged in age from 19 to 23 years with a mean age of 21 years.
II. EXERCISE PROGRAM

All subjects in the three exercise groups reported three times per week and exercised only the preferred arm for six weeks. At the beginning of the first exercise period each subject was given an exercise record sheet with his name and group number on it. At the end of each exercise period the record sheet was initialed by the experimenter. Subjects were instructed to perform their exercise at home if for some legitimate reason they were unable to report for their workout. Only nine per cent of the total exercise workouts were performed outside of the laboratory. Temperature in the exercise room ranged from 76 degrees to 85 degrees throughout the study with the average being 80.6 degrees.

Subjects in the autosuggestion exercise group performed five autosuggested contractions each exercise period. The exercise involved an isotonic contraction by means of autosuggestion, of the muscles utilized in elbow flexion. The contraction was initiated with the forearm and upper arm forming a 90 degree angle at the elbow joint and as arm flexion progressed a suggestion was given that a very heavy weight was being lifted. The average amount of time taken by the group to perform five autosuggested contractions through the study was eight minutes.

The isometric exercises were performed with the subject seated in a chair especially designed to measure elbow flexion strength. The
forearm and upper arm formed a right angle as the subject contracted against an immovable strap connected to the base of the chair by means of a cable. The isometric exercise position was the same as the elbow flexion strength test used in the study. (See Figure 7, page 58). The "all out" isometric effort was held for ten seconds with the investigator audibly counting off the seconds and recording the isometric contraction effort for each individual as measured by the cable tensiometer. Each isometric exercise trial was recorded and read to each subject in order to motivate them to greater efforts.

The static exercise group performed five fifteen second static contractions of the preferred arm with a forty-five second rest between each. Fifteen second static contractions were selected because the experimenter found in pre-study trials that students could hold an "all out" fifteen second static contraction, but felt that further contraction was less than maximal. The arm rested on a folded towel on the desk top at approximately a 90 degree angle and the biceps was maximally contracted with resistance being afforded by the simultaneous contraction of the antagonistic triceps muscle as shown in Figure 1. The subjects were constantly encouraged to perform maximum static contraction exercises throughout the study.
III. PRE-STUDY ORIENTATION

Each subject selected a period in which to be measured and to exercise and reported at the same hour throughout the study. There were not more than twelve students reporting during any one hour. During a ten day period prior to the administration of initial measurements, subjects in the study participated in an orientation session designed to instruct and familiarize them with the correct execution of the elbow flexion strength test and the performance of the exercise in which they were to engage during the study.
In the first orientation session, after designating and explaining group assignments, an attempt was made to impress the students with the importance of their role in the study. The subjects were told that the purpose of the study was to investigate the effect of the three types of muscular contraction—autosuggested, isometric, and static—upon arm strength and size of both the preferred and non-preferred arm, although only the preferred arm would be exercised. It was further explained that no conclusive experimental evidence was available to show that one type of exercise would necessarily be more beneficial than another, or that exercising one arm would increase the strength of the other, but that none of the exercises performed would be harmful. The purpose and nature of the Physiograph in the study was also revealed to the students.

Personal information questionnaires (See Appendix B) were then filled out by each student in order to furnish the researcher with background information about each subject which might prove meaningful. The students were told that upon the completion of the study their names would be eliminated and only their number would remain attached to their record.

In the second orientation session the correct technique involved in executing the elbow flexion strength test on the cable tensiometer was demonstrated and all subjects in each of the four groups were given two test trials with both the right and left arms. The score of each trial was recorded and corrections in technique were made by the
investigator. The elbow flexion strength test trials were repeated by each subject during the third orientation session which made a total of four trials with each arm prior to the administration of the initial strength test. Many individuals showed considerable improvement between the orientation trials and pre-study elbow flexion strength tests which possibly would have affected the results of the study had the orientation trials not been provided.

While performing the two strength test practice trials included in the second and third orientation sessions, those students assigned to the Isometric Exercise Group practiced their ten second "all out" isometric exercise by holding the contraction upon reaching maximum output as indicated by the cable tensiometer.

The Static Contraction Group performed two 15 second static contractions in each of the second and third orientation sessions after instruction was given in the technique of opposing the contraction of the biceps by means of contracting the antagonistic muscle, the triceps.

During the last 25 minutes of the second orientation session instruction in the autosuggestion technique of muscular contraction was begun for the Autosuggestion Exercise Group. The technique which was devised by the author through self-experimentation and which had previously been used in a pilot study by the author was revised

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1Bowers, op. cit.
slightly for this study. The subjects were seated in desks with the dominant hand placed palm down on the desk top which was padded by means of a folded towel. The following suggestions with appropriate pauses and variations being made for individual response to suggestion were given by the author to each subject:

You should be completely relaxed now and if you will look at your right hand as it lies on the desk top, you will become particularly aware of some things about the hand to which you normally do not pay attention. You will have a keen awareness of such things as the wrinkled skin around the joints of your fingers, the pores of your skin and even the joints of your fingers, the pores of your skin and even the hairs on the back of your hand. Your fingers feel as though they perhaps want to draw together and they may in fact do so.

Now, get a mental image of your hand, a picture of it in your mind; for in a few seconds I will ask you to close your eyes and visualize your hand as it lies on the desk top. All right now, if you will, close your eyes and picture your hand. You will now become aware of the texture of the desk top, the temperature of the desk top, and possibly you will feel the air passing through the hair on the back of your hand, like a gentle breeze blowing through blades of grass.

Presently your hand will begin to feel light. It is now becoming increasingly light, lighter, lighter. As it becomes lighter it will want to lift off the desk top. The lighter it becomes the higher it will rise and the higher it rises the lighter it will become. As your hand clears the desk top it will continue to rise higher and higher becoming lighter and lighter. You are aware that your hand is lifting off the desk, but it is doing so without your voluntarily aiding it.

Perhaps you will want to imagine your hand as being as light as a balloon filled with gas. Imagine the balloon being released by a small boy. It is rising up, up above the tallest tree tops, up, up, to the clouds. As your hand becomes lighter it continually rises higher, up, up, up. If you wish, imagine your hand as a feather drifting upward on a breezy day. It drifts upward, higher and higher, up, up, lighter, and lighter. Your hand will rise until it reaches your shoulder and then it will return slowly to the desk top.
A view of the hand elevation exercise used in the autosuggestion training period is shown in Figure 2, page 49.

The subjects were then asked to place their hands with palms facing upward on the desk top with the arm bent so that the arm and forearm formed a right angle at the elbow and were instructed to concentrate on the biceps muscle. The following suggestions were then given:

From your knowledge of the structure of a muscle, you know that the biceps is composed of many thousands of tiny muscle fibers. It is composed of thousands of minute muscle fibers, each being stimulated by its individual nerve fiber.

FIGURE 2

HAND ELEVATION DURING AUTOSUGGESTION TRAINING SESSION
As you concentrate on the muscle, the muscle fibers of the biceps will be stimulated. You will perhaps feel a tingling sensation in the muscle and may even see the muscle twitching as the muscle fibers are stimulated and begin to contract.

Now as you close your eyes, continue to concentrate on the biceps by having a mental picture of the muscle as it continues to contract. You can feel it contracting and pulling as it contracts. Naturally, as the muscle contracts, the hand and lower arm will be lifted. More muscle fibers are shortening and as they contract the hand rises higher and higher. The muscle is becoming firm and hard. You might imagine it as being a bar of steel for it is that hard.

Outside noises will not disturb you while performing your autosuggestion exercises and the more you practice the easier it will become to bring about an autosuggested muscular contraction.

As your muscle becomes harder and harder, the lower arm rises higher and higher. As your arm reaches your shoulder all of the muscle fibers of the biceps will be contracted, completely and fully. Now continue to suggest to yourself for the next three minutes that your muscle will continue to contract.

The subjects were asked to practice the autosuggested arm flexion exercise at home before the next orientation session, but for not more than one ten minute practice period.

A second twenty-five minute training session in the autosuggestion technique was conducted during the latter part of the third orientation session. The researcher reminded the subjects that relaxation was important and that "trying too hard" in the autosuggestion technique would create tenseness which would only interfere with their concentration. An elbow flexion contraction was then performed by the subjects with the aid of suggestions from the investigator as described in the preceding paragraphs. This was followed by an autosuggested elbow flexion performed with a suggestion being given that a dumbbell of
light weight was being placed in the hand. Actually a cylindrical shaped wood block weighing three-fourths of an ounce was placed in the individual's hand. The following suggestions were issued to introduce the effects of lifting a suggested weight after initiating muscle contraction in the manner previously described:

As the weight is placed in your hand you can feel the downward pull of the weight. Your arm may even start to move slowly downward, but you have the necessary strength to overcome it and by concentrating on contracting more fibers you can overcome it. Your muscle fibers have the necessary size and strength, all you have to do is strongly suggest that they will contract and you will lift the weight. Your biceps muscle is now becoming as hard as a rock.

FIGURE 3

INITIATING AUTOSUGGESTED ELBOW FLEXION
As you practice your autosuggestion contractions, outside noises will not disturb you and the more you perform the autosuggested contractions the heavier the weight will become and the greater the contractions of your biceps.

As your hand rises higher and higher you can constantly feel the downward pull of the weight, but your muscle will contract until it is fully and completely contracted. As your muscle becomes completely contracted it will become as hard as a bar of steel. Upon reaching a completely flexed position the muscle will continue to contract until it reaches its completed and full contraction.

FIGURE 4

COMPLETING ELBOW FLEXION CONTRACTION WITH SUGGESTED WEIGHT

Figures 3 and 4 show the performance of the autosuggested elbow flexion contraction in the initial and full contraction stages. The
exercises were performed over a range of elbow flexion movement beginning with 90 degrees and continuing to full flexion. The small wooden peg grasp in the hand symbolizes the heavy weight being lifted.

The outcomes of the study were dependent on the co-operation of all subjects in the study. The co-operation of the subjects in the autosuggestion group was especially important since there was no way to measure the degree to which the individual was performing the autosuggested contraction. An attempt was made throughout the study to impress upon the subjects the importance of the investigation and of their role in it.

In a previous study it was noted that a loss of awareness of the exact position of the lower arm was experienced while performing elbow flexion by means of autosuggestion. In answer to a question on a questionnaire administered during the fifth week of the study concerning the position of the lower arm during autosuggested elbow flexion all subjects expressed doubt of knowing its exact position, and verbalized about a tingling or burning sensation in the arm.

The subjects then performed an autosuggested contraction without any help from the investigator by utilizing the autosuggestion techniques they had been taught. The students were asked to attempt to perform

\[2\text{Bowers, op. cit.}\]
five autosuggested contractions before the fourth session.

The fourth session was spent with the group performing two autosuggested contractions on their own. Before the initial measurements were made all subjects were able to perform five autosuggested contractions with a suggested heavy weight. The control group practiced only the elbow flexion strength test during the orientation sessions.

IV. MEASUREMENT OF FOREARM AND BICEPS GIRTHS

Anthropometrical measurements of forearm and biceps girths for all subjects were made prior to the beginning of the exercise program. Measurements were taken each day before the administration of the elbow flexion strength test and before the individual engaged in any physical exercise. A steel tape was used and measures recorded to the nearest 1/8 of an inch. The results in inches were then converted to centimeters to facilitate statistical computations. Measures were recorded of the girths of the right forearm and biceps and left forearm and biceps. The above sequence of measurement was followed throughout the study. Measurements were made on two different days and an average of the two measures represented the girth size of the right and left forearms and biceps.

Right and left forearm girth measurements were taken with the subject in a standing position with the arm and fingers extended, as
shown in Figure 5, below. Several measures of the circumference of the forearm at various positions from the elbow joint to six inches below it were made and the largest reading was recorded.

FIGURE 5

FOREARM GIRTH MEASUREMENTS

Right and left biceps girth measurements were recorded with each individual seated in the elbow flexion strength testing chair as shown in Figure 6, page 56. The subject's arm was placed on the arm rest with the elbows braced against the back rest of the chair which caused the upper arm and forearm to form a 90 degree angle at the elbow joint. In an attempt to control the amount of contraction of the
biceps muscle, the cable tension strap was placed over the student's wrist and he contracted only until the cable was taut. Several measures of the biceps girth at various levels were made and the largest recorded.

Measurement of forearm and biceps girths made after three and six weeks of exercise followed the same procedure.
Reliability coefficients of .96 and .94 for the forearm and biceps girth measurements, respectively, were determined by comparing the pre-study measurements of the first day with those of the second day by means of the Pearson Product Moment Method.

V. ELBOW FLEXION STRENGTH TESTS

After completing the anthropometrical measurements, the strength of the forearm flexors in maximal effort was measured with a cable tensiometer. All strength tests throughout the study were administered by the investigator. A specially adapted armchair positioned the seated subject's forearm at a right angle to his upper arm. A 1 1/2 inch web belt fastened over the subject's wrist was attached to a 1/16 inch cable that descended perpendicularly and at right angles to the forearm to fasten to a hook at the base of the chair. The strap which was innerlined with foam rubber was placed over the wrist at the point of the distal condyles of the ulnar and radius. Cable tension readings of elbow flexion contractions were converted to pounds. The position of the subject for the administration of the elbow flexion strength test is shown in Figure 7, page 58.

Strength tests were administered on alternate days with one day of rest between. Two elbow flexion strength trials were administered for each the right and left arm. Trials were alternated from the right to left arm with at least a one minute rest between each trial of the same
Upon the completion of the second day of testing each individual had a total of four elbow flexion strength test scores for each arm. The highest of the four scores was selected to represent the initial strength of that arm.

Strength tests were administered before beginning the exercise program, after a three weeks period, and after six weeks of exercise. Reliability of the cable tension strength testing was determined by
correlating the subjects' elbow flexion strength scores in the first trial on one day with that of his first trial on the next testing session 48 hours later. Reliabilities of .95 for the right arm and .90 for the left arm were obtained.

VI. MUSCLE ACTION POTENTIAL MEASUREMENT DURING AUTOSUGGESTED ELBOW FLEXION

Muscle action potential recordings were made of 17 of the 18 subjects in the autosuggestion group during their initial exercise session, at the end of the third week of exercise, and upon completion of exercise at the end of six weeks. A difference of only three degrees in room temperature existed between initial action potential testing and the room temperature during the third week and final muscle action potential measurements which was not considered to have any adverse affect on the reliability of the measures.

E. M. G. recordings were obtained by means of the three channel Physiograph with a Hi-Gain Preamplifier of a sensitivity which exceeds 30 microvolts/cm. The Hi-Gain Preamplifier was placed two feet from the subject and recordings were made by means of 36 inch leads as shown in Figure 8, page 60. This procedure was used to eliminate outside electrical interference. The processor in the main unit, a direct coupled balanced power amplifier, enlarged the electrical signals received from the Hi-Gain Preamplifier and forwarded them to the recording pen for graphic reproduction. A constant paper speed of
6 centimeters per second was maintained throughout the study with the
time marker set at one second intervals.

An arbitrary amplitude setting was selected to keep the graphic
recordings within a range corresponding to an 8 centimeter linear
excursion of the recording pen. The optimum amplitude settings were
determined after obtaining muscle action potential recordings during
autosuggested contraction of a sampling of subjects during the pre-study
orientation week. The same amplitude settings were maintained through­
out the entire study. No attempt was made to calibrate the degree of pen
deflection to microvolts readings since this study was concerned only
with the amount of change throughout the study in muscle action
potentials during autosuggested contraction.

Muscle action potential recordings were made of the biceps muscle
by means of external sterling silver contour plate electrodes 1 1/2 x
1 1/2 inches in size. Two electrode plates were sewn into a 6 x 7 inch
heavy cloth which formed a half sleeve when placed over the belly of
the biceps muscle. The electrodes were 1 1/2 inches apart at their
nearest point. To insure the same position of the electrodes on the
muscle the cloth was spread each time equi-distant over the belly of
the biceps with the bottom edge of the cloth parallel to the crease of the
elbow joint with the arm in an extended position. The biceps muscle
was wiped with a towel and the electrode plates were amply covered
with electrocardiogram jelly before they were placed on the muscle.
The electrodes were held securely in place by two adjustable rubber
straps which were wrapped around the arm. Electrical silence as
indicated by no pen deflections with the muscle in a resting state was
obtained before the beginning of each recording. Figure 8, page 60,
shows muscle action potential recordings being made during autosuggest-
ed contraction of the forearm flexor muscles.

The subjects in the autosuggestion group were instructed to bring
about a complete flexion of the lower arm with a suggested weight and
to continue to suggest contraction after reaching the full range of move-
ment. During the fifth autosuggested contraction of their exercise work-out muscle action potential recordings were made of the last five seconds of the contraction in which the arm was in a fully flexed position.

**Interpreting Muscle Action Potential Recordings.**

The height of spike potentials appearing every one-half second over a five second duration was measured. This is similar to a technique of quantitating action potential recordings as reported by Reeder 4 The total of the measures of the ten spike potentials sampled over a five second period of an autosuggested contraction expressed in arbitrary units represented the subject's muscle action potential measurement. A reliability coefficient of .90 was found between muscle action potential measures recorded during two consecutive autosuggested contractions by means of the Pearson Product Moment Method.

**VII. RECORDINGS OF BICEPS AND TRICEPS MUSCLE ACTION POTENTIALS DURING AUTOSUGGESTED ELBOW FLEXION**

This phase of the study which involved simultaneous action potential recordings of the biceps and triceps muscles during autosuggested contraction was conducted during the week following the completion of all final measurements in the study. Action potential recordings of the

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biceps muscle during autosuggested contraction were made in the same manner with the same amplitude settings as previously described. In addition, two sterling silver contour surface electrodes, 1 1/2 x 2 1/2 inches, connected to a Hi-Gain Preamplifier were placed on the triceps muscle in order to record the action potentials of the triceps muscle during autosuggested elbow flexion. An amplitude setting which gave pen deflections not exceeding 8 cm. was selected and maintained for each recording. No attempt was made to equalize amplitude settings.
for E. M. G. recordings of the biceps and triceps muscles since the experimenter was only concerned with obtaining a graphic relationship between the E. M. G. recording of the two muscles during autosuggested contraction.

E. M. G. recordings were made of an autosuggested elbow flexion over an entire range of movement. The subject was asked to perform an autosuggested contraction and he was instructed that upon a given verbal signal he was to suggest the presence of a very heavy weight in his hand. When the verbal signal was given to the subject the investigator pressed an automatic marker on the Physiograph which indicated on the recording the time the verbal signal was given.

VIII. TREATMENT OF DATA

The Louisiana State University Computer Research Center was utilized in the statistical analysis of the data of the study. The raw data were entered on IBM score sheets from which the data were then read and punched onto IBM cards used to compute the final results.

An analysis of covariance was computed for between group differences in Groups A, B, C, and D for the qualities of arm strength and size after 3 weeks and 6 weeks of training.

The measures of arm strength and size which were found to be significantly different after training by means of the covariance F test were further analyzed by means of a one tailed t test of the significance
of the difference between pre-exercise and post-exercise mean gains. An extension of Duncan's New Multiple Range Test for unequal groups was then used to compute the significance of the differences of strength increases among the three exercise groups in the study.

The significance of the difference of mean gains of action potential measures recorded during autosuggested muscle contraction were computed for the subjects in the autosuggestion group after 3 weeks and 6 weeks of exercising by a one tailed t test.

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CHAPTER IV

RESULTS AND DISCUSSION

The experimental design used in this study consisted of four groups, three exercise groups and one control group, with subjects randomly assigned to each group. Due to differences in the initial means of the groups, the statistical technique selected to analyze the data was an analysis of covariance. The qualities which were analyzed by analysis of covariance were elbow flexion strength and forearm and biceps girth size of exercised and unexercised arms as they were affected by autosuggested, isometric, and static muscular contraction exercises. The 1 per cent level of confidence was selected for tests of significance in this study; however, tests not showing significance at the 1 per cent level were tested at the 5 per cent level.

I. ESTABLISHING THE SIGNIFICANCE OF THE BETWEEN GROUP DIFFERENCES DUE TO THE EFFECTS OF TRAINING

Significance of Strength Increase of Exercised Arm.

The results of the analysis of covariance showed significant differences existed between Groups A, B, C, and D in the measurement of elbow flexion strength of the exercised preferred arm upon completing
both 3 weeks and 6 weeks of training. As seen in Table III, the F test results for the 3 week and 6 week exercise periods were 12.4 and 22.8 respectively. Both of these F's were highly significant at the 1 per cent level of confidence; therefore, showing significant elbow flexion strength increase due to exercise.

Further computations were made to analyze which of the three types of exercises used in the study contributed most effectively to strength development.

A one tailed t test of the significance of the difference between the initial means and mean elbow flexion strength of the exercised arm for each of the four groups after 3 weeks training showed both Group A (Autosuggestion Exercise Group) and Group B (Isometric Exercise Group) to have increased significantly at the 1 per cent level of confidence.

After six weeks of training, significant elbow flexion strength mean gains were found for the isometric, static, and autosuggestion exercise groups at the 1 per cent level. The control group, whose members performed no exercise for the six week period, had a significant decrease in mean arm flexion strength at the 1 per cent level as computed by means of a one tailed t test. (See Table I)

A further comparison between the autosuggestion, isometric, and static contraction exercises as to their effectiveness in developing strength of the elbow flexor muscles was made. Duncan's New Multiple
TABLE I

ONE TAILED t-TEST OF SIGNIFICANCE OF MEAN GAINS IN ELBOW FLEXION STRENGTH OF THE EXERCISED ARM FOR THE FOUR GROUPS AFTER THREE WEEKS AND SIX WEEKS OF EXERCISE

<table>
<thead>
<tr>
<th>Training Programs</th>
<th>Mean Gains</th>
<th>df</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isometric Group (3 Weeks)</td>
<td>4.4 lbs.</td>
<td>14</td>
<td>6.8</td>
<td>.01</td>
</tr>
<tr>
<td>Isometric Group (6 Weeks)</td>
<td>8.2 lbs.</td>
<td>14</td>
<td>9.87</td>
<td>.01</td>
</tr>
<tr>
<td>Autosuggestion Group (3 Weeks)</td>
<td>2.3 lbs.</td>
<td>18</td>
<td>2.77</td>
<td>.01</td>
</tr>
<tr>
<td>Autosuggestion Group (6 Weeks)</td>
<td>2.9 lbs.</td>
<td>18</td>
<td>2.98</td>
<td>.01</td>
</tr>
<tr>
<td>Static Group (3 Weeks)</td>
<td>1.4 lbs.</td>
<td>13</td>
<td>1.25</td>
<td></td>
</tr>
<tr>
<td>Static Group (6 Weeks)</td>
<td>4.7 lbs.</td>
<td>13</td>
<td>3.98</td>
<td>.01</td>
</tr>
<tr>
<td>Control Group (3 Weeks)</td>
<td>-2.7 lbs.</td>
<td>16</td>
<td>1.18</td>
<td></td>
</tr>
<tr>
<td>Control Group (6 Weeks)</td>
<td>-2.5 lbs.</td>
<td>16</td>
<td>3.00</td>
<td>.01</td>
</tr>
</tbody>
</table>

Range Test for unequal groups showed at the 5 per cent level of confidence that the isometric contraction exercises were significantly more effective in developing strength than either static contraction or autosuggested contraction exercises. No significant difference was found between the strength increases of the subjects in the static exercise.

2Kramer, *op. cit.*
group and those in the autosuggestion exercise group. The computation of the between group comparisons of individual strength increase utilizing Duncan's New Multiple Range Test for unequal groups is shown in Appendix F and the results are shown in Table II, below.

### TABLE II

---

**RESULTS OF DUNCAN'S NEW MULTIPLE RANGE TEST FOR UNEQUAL GROUPS FOR ELBOW FLEXION STRENGTH OF EXERCISED ARM**

<table>
<thead>
<tr>
<th></th>
<th>Mean Gain</th>
<th>Number of Subjects</th>
<th>Z</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group B</strong></td>
<td>8.2 lbs.</td>
<td>14</td>
<td>20.9</td>
<td>.01</td>
</tr>
<tr>
<td>Isometric Exercise</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Group C</strong></td>
<td>4.7 lbs.</td>
<td>13</td>
<td>12.8</td>
<td>.05</td>
</tr>
<tr>
<td>Static Exercise</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Group A</strong></td>
<td>2.9 lbs.</td>
<td>18</td>
<td>6.98</td>
<td></td>
</tr>
<tr>
<td>Autosuggestion Exercise</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

1. Isometric exercise strength gain is significantly greater than autosuggestion exercise strength gains at the 1 per cent level.
2. Isometric exercise strength gain is significantly greater than static exercise strength gain at the 5 per cent level.
3. No significant difference existed between static exercise strength gains and autosuggestion exercise strength gains.

Significance of Forearm and Biceps Girth Size Changes of Exercised Arm.

The F tests, shown in Table III, of the changes of forearm girth size
of the exercised arm for the 3 week and 6 week periods of training were .65 and .55, neither of which was significant. Groups A, B, C, and D all showed slight but not significant mean decreases in forearm girth size.

The size of the biceps girth of the exercised arm for each of the four groups showed a slight decrease but the analysis of covariance produced F tests which were not significant of 1.13 after 3 weeks of training and 2.59 after 6 weeks of training which were not significant. The group means of forearm and biceps girths are presented in Appendix D.

Although a significant increase in the strength of the elbow flexor muscles was produced by each of the three types of exercises performed in the study, this increase was not accompanied by an increase in the size of the flexor muscles.

Significance of Strength Increase of the Unexercised Arm.

The F tests of the elbow flexion strength gains of the unexercised contralateral arm as shown in Table IV, revealed that the between group differences were not significant after both the 3 and 6 weeks periods of training. The F test results for the 3 week and 6 week periods were 1.03 and .99 respectively. The results indicate that a slight, but not significant cross transfer of strength occurred between the exercised and unexercised limbs. The group means of elbow flexion strength are presented in Appendix E.
### TABLE III

RESULTS OF ANALYSIS OF COVARIANCE OF BETWEEN GROUP DIFFERENCES OF THE MEASUREMENTS OF THE EXERCISED ARM

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sums of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength of Exercised Arm (3 Weeks)</td>
<td>Between 413</td>
<td>3</td>
<td>137</td>
<td>12.4</td>
</tr>
<tr>
<td></td>
<td>Within 624</td>
<td>56</td>
<td>11.1</td>
<td></td>
</tr>
<tr>
<td>Strength of Exercised Arm (6 Weeks)</td>
<td>Between 993</td>
<td>3</td>
<td>331</td>
<td>22.8</td>
</tr>
<tr>
<td></td>
<td>Within 817</td>
<td>56</td>
<td>14.5</td>
<td></td>
</tr>
<tr>
<td>Forearm Girth of Exercised Arm (3 Weeks)</td>
<td>Between 331</td>
<td>3</td>
<td>10.3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Within 880</td>
<td>56</td>
<td>15.7</td>
<td></td>
</tr>
<tr>
<td>Forearm Girth of Exercised Arm (6 Weeks)</td>
<td>Between 24</td>
<td>3</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Within 814</td>
<td>56</td>
<td>14.5</td>
<td>1</td>
</tr>
<tr>
<td>Biceps Girth of Exercised Arm (3 Weeks)</td>
<td>Between 28</td>
<td>3</td>
<td>9.3</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td>Within 4580</td>
<td>56</td>
<td>81.7</td>
<td></td>
</tr>
<tr>
<td>Biceps Girth of Exercised Arm (6 Weeks)</td>
<td>Between 99</td>
<td>3</td>
<td>33</td>
<td>2.59</td>
</tr>
<tr>
<td></td>
<td>Within 715</td>
<td>56</td>
<td>12.7</td>
<td></td>
</tr>
</tbody>
</table>

1 The above analysis of covariance is based on the data of sixty-one subjects.

2 Significant at the one per cent level of confidence.

Significance of Forearm and Biceps Girth Size Changes of Unexercised Arm.

The between group differences in forearm girth size of the unexercised arm was not significant as indicated by F tests of .36 and 1.13 respectively.
TABLE IV

RESULTS OF ANALYSIS OF COVARIANCE OF BETWEEN GROUP DIFFERENCES OF THE MEASUREMENTS OF STRENGTH AND FOREARM AND BICEPS GIRTH SIZE OF THE UNEXERCISED ARM AFTER THREE WEEKS AND SIX WEEKS OF TRAINING

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sums of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength of Unexercised Arm (3 Weeks)</td>
<td>Between</td>
<td>10</td>
<td>3</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>Within</td>
<td>190</td>
<td>56</td>
<td>3.2</td>
</tr>
<tr>
<td>Strength of Unexercised Arm (6 Weeks)</td>
<td>Between</td>
<td>53</td>
<td>3</td>
<td>17.6</td>
</tr>
<tr>
<td></td>
<td>Within</td>
<td>1048</td>
<td>56</td>
<td>18.7</td>
</tr>
<tr>
<td>Forearm Girth of Unexercised Arm (3 Weeks)</td>
<td>Between</td>
<td>19</td>
<td>3</td>
<td>6.3</td>
</tr>
<tr>
<td></td>
<td>Within</td>
<td>264</td>
<td>56</td>
<td>4.7</td>
</tr>
<tr>
<td>Forearm Girth of Unexercised Arm (6 Weeks)</td>
<td>Between</td>
<td>14</td>
<td>3</td>
<td>4.6</td>
</tr>
<tr>
<td></td>
<td>Within</td>
<td>712</td>
<td>56</td>
<td>12.7</td>
</tr>
<tr>
<td>Biceps Girth of Unexercised Arm (3 Weeks)</td>
<td>Between</td>
<td>157</td>
<td>3</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>Within</td>
<td>1625</td>
<td>56</td>
<td>27</td>
</tr>
<tr>
<td>Biceps Girth of Unexercised Arm (6 Weeks)</td>
<td>Between</td>
<td>61</td>
<td>3</td>
<td>20.5</td>
</tr>
<tr>
<td></td>
<td>Within</td>
<td>1209</td>
<td>56</td>
<td>21.5</td>
</tr>
</tbody>
</table>

1 The above analysis of covariance is based on the data of sixty-one subjects.

2 None of the above F tests were significant at either the one or five per cent levels of significance.

The differences between groups in biceps girth size measurements were not significant after 3 weeks and 6 weeks of exercise as shown by F tests results of 1.8 and .95 respectively.

The size of the elbow flexor muscles of the unexercised contralateral
limb was not affected by exercising the opposite limb. In Appendix E are presented the group means of forearm and biceps girth.

Significance of Increase in Muscle Action Potentials Recorded During Autosuggested Contraction.

Table V, below, shows the result of a one tailed t test of the significance of the difference between initial mean muscle action potential recordings during autosuggested muscular contraction and recordings after 3 weeks of training was 5.94. This was a significant mean increase at the 1 per cent level. The mean difference between action potential recordings at the 3 week period and final recordings showed an increase which was significant at the 5 per cent level.

TABLE V

RESULTS OF A ONE TAILED t TEST OF THE SIGNIFICANCE OF THE INCREASE OF MUSCLE ACTION POTENTIAL RECORDINGS DURING AUTOSUGGESTED MUSCULAR CONTRACTION AFTER THREE WEEKS AND SIX WEEKS OF TRAINING

<table>
<thead>
<tr>
<th>Initial Mean</th>
<th>3 Weeks Mean</th>
<th>Mean Gain</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>76.8</td>
<td>127.4</td>
<td>50.4</td>
<td>5.94</td>
<td>.01</td>
</tr>
<tr>
<td>3 Weeks Mean</td>
<td>6 Weeks Mean</td>
<td>Mean Gain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>127.4</td>
<td>139.3</td>
<td>11.9</td>
<td>1.78</td>
<td>.05</td>
</tr>
</tbody>
</table>

Note: The above results are based on the data of 17 subjects.
These results indicate that the subjects in the autosuggestion group became significantly more proficient in the performance of autosuggestion muscular contraction in terms of stimulating more motor units and bringing about more contraction of more muscle fibers during the first three weeks of the study. After the first three weeks however improvement in the ability to bring about a more forceful muscular contraction leveled off and between the third and sixth weeks the increase in action

![Graph showing muscle action potential recordings](image)

**FIGURE 10**

**INITIAL, THREE WEEK, AND FINAL MUSCLE ACTION POTENTIAL RECORDINGS OF TYPICAL SUBJECT DURING AUTOSUGGESTED CONTRACTION**
potential recordings was small. The increase was however significant
at the 5 per cent level of confidence.

The initial, three weeks, and final muscle action potential recordings
during autosuggested muscular contraction of a typical subject is
presented on page 74 in Figure 10.

II. DISCUSSION

The primary purpose of this study was to explore the effect of auto-
suggested muscular contraction on muscle strength and size, therefore
the major portion of this discussion section will be devoted to comments
on the findings of the study concerning autosuggested contraction and to
observations of the subjects in the autosuggestion exercise group.

All of the 18 subjects in the autosuggestion exercise group were able
to learn to bring about a muscular contraction by means of autosuggestion
after three one hour sessions of instruction by the investigator. Subjects
showed substantial increases in the force of their muscular contraction
during the performance of an autosuggested exercise for the first three
weeks of training as evidenced by a significant group mean increase in
action potential measures taken during the contraction. However
increase in the force of the autosuggested contraction which took place
between the third and sixth week of the study was not as great. The
initial mean time used to perform five autosuggested contractions was 12
minutes. This mean time was reduced to 8 minutes at the end of the 3
week period and to 5 minutes at the end of the training period. The above
findings indicate that the subjects in the autosuggestion exercise group became increasingly more proficient in bringing about a more forceful muscular contraction by means of autosuggestion during the first three weeks of the study and thus perhaps greater gains in elbow flexion strength could be expected during the second 3 weeks of the study. This was not the case, however, as shown by a mean elbow flexion strength increase in the autosuggestion group of 2.3 lbs. during the first three weeks of training and a mean gain of only .6 lbs. during the last three weeks.

From the standpoint of the immediate and practical application of autosuggested muscular contraction to the development of strength, it can be said that significantly more strength can be developed by isometric exercise and the same amount of strength that was developed using autosuggestion can be developed by static type exercise. Both isometric and static contraction exercises involved much less time per exercise period and are easier to learn. However, all of this does not eliminate the possibility of the use of autosuggestion exercises in the re-education of muscles in cases of injury such as severed nerves or paralysis resulting from degenerated periphal nerves. As shown in this study strength can be significantly improved in the normal muscle by means of autosuggested contraction and can perhaps serve as a needed catalyst between the psychological and physical in rehabilitation.

In answer to questions concerning the autosuggestion technique posed
by means of a questionnaire to subjects in the autosuggestion exercise group some interesting observations were recorded. (See Appendix C for questionnaire) Only two subjects had ever experienced anything like the autosuggested muscular contraction. Both indicated it was similar to but not the same as experiencing a hypnotic trance. The objects used as a suggested heavy weight by the subjects ranged from a dumbbell to a large bag of canned goods to a scoop of dirt. Fifteen of the subjects felt that the autosuggested muscular contractions would make them stronger. Only two of the subjects acknowledge being disturbed by outside noises during the performances of their autosuggested exercise although many such disturbances were present in the hallway and on the sidewalks outside the laboratory.

The necessity of subjects becoming thoroughly familiar with strength testing devices prior to the administration of initial strength tests in experimental studies is felt by this investigator to be highly desirable. This is based on the improvement shown by subjects on the elbow flexion strength test during the orientation week preceding this study.

The simultaneous action potential recordings of the biceps and triceps muscle showed that thirteen of the fourteen subjects measured in the autosuggestion group showed an increase in muscle action potential measures within 3 seconds after receiving a signal to suggest to them-

\[1\] Note: During the autosuggestion technique instruction sessions the investigator repeatedly suggested that outside noises would not be distracting.
selves that they were lifting a very heavy weight. In three of the subjects the increase in action potential measures after the signal were immediate. The one subject not increasing had showed marked increase in muscle action potentials of the biceps muscle on the physiograph recording prior to the signal. The implication in these results is that the use of the suggested heavy weight helps the individual to bring about a more forceful muscular contraction. A typical recording of action potential measures of the biceps and triceps is shown in Figure 11 below.

**FIGURE 11**

SIMULTANEOUS RECORDING OF ACTION POTENTIALS OF THE BICEPS AND TRICEPS DURING AUTOSUGGESTED CONTRACTION
The failure of the members of the three exercise groups to increase in forearm or biceps girth during the six weeks of exercise can possibly be attributed to the fact that the mean age of the subjects in the study was 21 years and all had completed four semesters of required physical education. The slight decrease in arm size which occurred in the three exercise groups and the control group was not significant, but can perhaps be due to measuring variation.
CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this study was to investigate the effect of autosuggested muscular contractions on the strength and size of the elbow flexor muscles as compared to the effect of isometric muscular contractions and static contractions, as a result of 3 weeks and 6 weeks of training. The strength and size development of the contralateral unexercised arm was also studied. Measurements of muscle action potentials during the performance of an autosuggested muscular contraction were recorded on a physiograph and comparisons were made of the change in action potentials throughout the study.

Sixty-one volunteer male students, whose mean age was 21 years, were involved in the study. Students were randomly assigned to one of four groups which included an autosuggestion exercise group, an isometric exercise group, a static contraction exercise group, and a control group whose members performed no exercise during the study.

Preceding the study a week of orientation was conducted in which subjects practiced the elbow flexion strength test and were instructed in the correct performance of their respective exercises.

Initial measurements included elbow flexion strength tests of the
right and left arm, forearm and biceps girth measures of both arms and action potential measures during autosuggested contraction. These measurements were repeated after 3 weeks and 6 weeks of exercise.

Each exercise group performed five repetitions of contractions of the elbow flexor muscles on three days a week for a six week period. Each isometric repetition was an "all-out" contraction performed for a 10 second duration and each static contraction exercise was held for 15 seconds. The average time consumed by the autosuggestion group in the performance of one autosuggested contraction was 1 minute and 36 seconds. Upon the completion of final strength test a simultaneous recording of the action potentials of the biceps and triceps muscles during an autosuggested muscular contraction was made and analyzed to study the effect of suggesting the lifting of a heavy weight on action potential measures of the biceps muscle and to study the role of the triceps muscle in autosuggested contraction.

An analysis of covariance was used to compute the between group difference for each of the qualities under investigation in the study. Further comparisons were made by means of a one tailed t test and Duncan's New Multiple Range Test for unequal groups.

The results of the study were:

1. Both the autosuggestion and isometric exercise groups showed a significant increase in elbow flexion strength at the 1 per cent level of confidence after 3 weeks of training; whereas the
static contraction exercise group showed no significant strength gains.

2. After six weeks of training the isometric, static, and autosuggestion exercises were all found to have produced significant increases in strength of the elbow flexor muscles at the 1 per cent level.

3. Isometric exercise was significantly more effective in developing elbow flexion strength than either static or autosuggestion exercises at the 1 per cent level of significance; but no significant difference was found to exist at the 1 per cent level between the effectiveness of static and autosuggested exercise after six weeks of exercise.

4. No significant increase in forearm and biceps girth size resulted from either of the three types of exercise used in the study.

5. No significant increase occurred in elbow flexion strength and forearm and biceps girth size of the unexercised contralateral limb in any of the four groups.

6. Muscle action potential recordings during the performance of autosuggested muscular contraction increased significantly at the 1 per cent level during the first three weeks of the study; but significant increase was found between the third and sixth weeks only at the 5 per cent level of confidence.

7. Thirteen of the fourteen subjects measured in the autosuggestion
static contraction exercise group showed no significant strength gains.

2. After six weeks of training the isometric, static, and autosuggestion exercises were all found to have produced significant increases in strength of the elbow flexor muscles at the 1 per cent level.

3. Isometric exercise was significantly more effective in developing elbow flexion strength than either static or autosuggestion exercises respectively at the 5 and 1 per cent level of significance; but no significant difference was found to exist at the 1 per cent level between the effectiveness of static and autosuggested exercise after six weeks of exercise.

4. No significant increase in forearm and biceps girth size resulted from either of the three types of exercise used in the study.

5. No significant increase occurred in elbow flexion strength and forearm and biceps girth size of the unexercised contralateral limb in any of the four groups.

6. Muscle action potential recordings during the performance of autosuggested muscular contraction increased significantly at the 1 per cent level during the first three weeks of the study; but significant increase was found between the third and sixth weeks only at the 5 per cent level of confidence.

7. Thirteen of the fourteen subjects measured in the autosuggestion
group showed an increase in action potential measures of the biceps muscle within 3 seconds after receiving a signal to suggest to themselves that they were flexing the elbow with a very heavy weight in the hand.

8. Increased action potential measures of the biceps during autosuggested contraction was accompanied by increased action potential measures of the triceps muscle.

II. CONCLUSIONS

Within the limits of this study the following conclusions are drawn:

1. Five autosuggested muscle contractions or five "all-out" isometric contractions performed three days per week for three weeks will produce significant strength increase.

2. Six weeks of training three days per week performing five isometric, static or autosuggested muscular contractions will significantly increase strength.

3. Isometric exercise is more effective in developing strength over a six weeks period than either static or autosuggested exercise.

4. There is no difference in the strength resulting from six weeks of training using a 15 second static contraction and training utilizing autosuggested muscular contraction.

5. Increase in muscle size does not result from isometric, static,
or autosuggested muscular contraction as performed in this study for a six weeks period.

6. No cross transfer of strength or size from the exercised to the contralateral unexercised arm occurred in this study.

7. Improvement in the force of the contraction of a muscle during autosuggested contraction as indicated by increased muscle action potential measurements occurs as a result of practice.

8. The suggestion of lifting a heavy weight used during the performance of autosuggested muscular contraction helps bring about a more forceful contraction as indicated by increased measurements of muscle action potentials.

Recommendations for Further Study.

Based on the findings and observations made during this study the investigator recommends the following investigations:

1. A study in a clinical setting which would explore the use of autosuggested muscular contraction in the rehabilitation of injured limbs involving severed nerves which have been rejoined surgically and/or paralysis resulting from degenerated peripheral nerves.

2. An investigation of the effects on muscular strength and endurance of a single autosuggested muscular contraction per workout held in continuous contraction for 3 minutes by means of suggestions.
3. A study of the development of muscle strength by means of autosuggested muscular contractions with an actual weight in the hand and autosuggested contraction against an immovable bar.

4. An exploration of the relationship of muscle action potential changes during voluntary contraction to strength increases resulting from various types of exercises.
SELECTED BIBLIOGRAPHY
SELECTED BIBLIOGRAPHY

A. BOOKS


B. PERIODICALS AND PUBLICATIONS


C. UNPUBLISHED MATERIALS


Egstrom, Glen W. Personal Correspondence, May 8, 1962.
APPENDIX
APPENDIX A

PRE-STUDY LETTER TO STUDENTS

University of Southwestern Louisiana
P. O. Box 657, USL
Lafayette, Louisiana
March 11, 1963

Dear

On March 25, 1963, I will be starting a research project dealing with building muscle strength and size. The results of this study could produce important information concerning strength building and muscle rehabilitation.

I wish to invite you to participate in this study as a subject and hope that you will be able to find the time to partake in this important project.

The study will last for six weeks, and after initial tests are made will require only about 15 minutes or less of your time on three days a week. If you feel you can help in this matter, please come by my office in the Men's Gymnasium on Tuesday, Thursday, or Saturday mornings between 8 and 12 p. m., or some other time at your convenience to speak with me about it. Incidentally, the exercise involved is not very strenuous.

There is the possibility that the subjects involved in the study, pending a research grant, will be paid for their efforts. Remember, you must contact me before March 25, 1963.

Thank you for your cooperation.

Cordially yours,

Louis E. Bowers
Men's Department of Health and Physical Education

LEB/bb
APPENDIX B

PRE-STUDY PERSONAL INFORMATION QUESTIONNAIRE

NAME       NUMBER       GROUP

AGE       CLASSIFICATION       MAJOR

DOMINANT HAND       WEIGHT       HEIGHT

List previous varsity athletic experience:

High School:__________________________________________
__________________________________________
__________________________________________

College:__________________________________________
__________________________________________
__________________________________________

List previous experience with weight training or isometric exercises:

__________________________________________
__________________________________________

Indicate any previous injury to right or left arm (broken bones, surgery, etc.)

__________________________________________

I hereby agree to cooperate in carrying out those things required of an individual in order to participate as a subject in this study to the best of my ability.

__________________________________________
SIGNATURE
APPENDIX C

QUESTIONNAIRE ADMINISTERED TO AUTOSUGGESTION GROUP

NAME __________________________

Have you ever experienced a sensation like that which you experienced in performing auto-suggested muscular contraction? _______ Explain.

________________________________________________________________________

What type of weight or resistance did you suggest that you were lifting during your auto-suggested exercises? __________________________

________________________________________________________________________

During an auto-suggested contraction, were you aware of the exact position of your lower arm at all times? __________________________

________________________________________________________________________

Upon completing an auto-suggested contraction and opening your eyes, was your lower arm in the exact position you thought it to be?

________________________________________________________________________

Where do you think the resistance you encountered in lifting a suggested heavy weight came from? __________________________

________________________________________________________________________

Do you think the auto-suggested exercises will make your arm stronger?

________________________________________________________________________

Were you unduly disturbed during your auto-suggested exercises by noises in the room or outside noises?

________________________________________________________________________
## APPENDIX D

**INITIAL, THREE WEEKS, AND FINAL MEANS OF ELBOW FLEXION STRENGTH, FOREARM GIRTHS, AND BICEPS GIRTHS OF THE EXERCISED ARM FOR THE FOUR GROUPS**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Group</th>
<th>Initial Test</th>
<th>3 Weeks Test</th>
<th>6 Weeks Test</th>
<th>Final Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Elbow Flexion</strong></td>
<td>Autosuggestion</td>
<td>82.9 lbs.</td>
<td>85.2 lbs.</td>
<td>85.8 lbs.</td>
<td>2.9 lbs.</td>
</tr>
<tr>
<td><strong>Strength</strong></td>
<td>Isometric</td>
<td>90.7 lbs.</td>
<td>95.1 lbs.</td>
<td>98.9 lbs.</td>
<td>8.2 lbs.</td>
</tr>
<tr>
<td></td>
<td>Static</td>
<td>81.8 lbs.</td>
<td>83.2 lbs.</td>
<td>86.5 lbs.</td>
<td>4.7 lbs.</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>88.1 lbs.</td>
<td>85.4 lbs.</td>
<td>85.6 lbs.</td>
<td>-2.5 lbs.</td>
</tr>
<tr>
<td><strong>Forearm Girth</strong></td>
<td>Autosuggestion</td>
<td>27.2 cm.</td>
<td>27.0 cm.</td>
<td>26.8 cm.</td>
<td>-0.4 cm.</td>
</tr>
<tr>
<td><strong>Girth</strong></td>
<td>Isometric</td>
<td>28.1 cm.</td>
<td>27.8 cm.</td>
<td>27.7 cm.</td>
<td>-0.4 cm.</td>
</tr>
<tr>
<td></td>
<td>Static</td>
<td>28.2 cm.</td>
<td>27.9 cm.</td>
<td>27.7 cm.</td>
<td>-0.5 cm.</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>28.1 cm.</td>
<td>27.7 cm.</td>
<td>27.5 cm.</td>
<td>-0.6 cm.</td>
</tr>
<tr>
<td><strong>Biceps Girth</strong></td>
<td>Autosuggestion</td>
<td>31.2 cm.</td>
<td>31.2 cm.</td>
<td>30.9 cm.</td>
<td>-0.3 cm.</td>
</tr>
<tr>
<td><strong>Girth</strong></td>
<td>Isometric</td>
<td>32.3 cm.</td>
<td>32.1 cm.</td>
<td>31.7 cm.</td>
<td>-0.6 cm.</td>
</tr>
<tr>
<td></td>
<td>Static</td>
<td>32.4 cm.</td>
<td>32.4 cm.</td>
<td>31.8 cm.</td>
<td>-0.6 cm.</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>33.2 cm.</td>
<td>33.1 cm.</td>
<td>32.8 cm.</td>
<td>-0.4 cm.</td>
</tr>
</tbody>
</table>
## Appendix E

Initial, Three Weeks, and Final Means of Elbow Flexion Strength, Forearm Girths, and Biceps Girths of the Unexercised Arm for the Four Groups

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Group</th>
<th>Initial Test</th>
<th>3 Weeks Test</th>
<th>6 Weeks Test</th>
<th>Final Test</th>
<th>Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elbow Flexion</td>
<td>Autosuggestion</td>
<td>75.3 lbs.</td>
<td>75.9 lbs.</td>
<td>77.1 lbs.</td>
<td>77.1 lbs.</td>
<td>1.8 lbs.</td>
</tr>
<tr>
<td></td>
<td>Isometric</td>
<td>82.3 lbs.</td>
<td>82.5 lbs.</td>
<td>85.1 lbs.</td>
<td>85.1 lbs.</td>
<td>2.8 lbs.</td>
</tr>
<tr>
<td></td>
<td>Static</td>
<td>78.3 lbs.</td>
<td>79.0 lbs.</td>
<td>80.7 lbs.</td>
<td>80.7 lbs.</td>
<td>2.4 lbs.</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>83.3 lbs.</td>
<td>82.4 lbs.</td>
<td>83.5 lbs.</td>
<td>83.5 lbs.</td>
<td>.2 lbs.</td>
</tr>
<tr>
<td>Forearm Girth</td>
<td>Autosuggestion</td>
<td>26.5 cm.</td>
<td>26.2 cm.</td>
<td>26.0 cm.</td>
<td>26.0 cm.</td>
<td>-.5 cm.</td>
</tr>
<tr>
<td></td>
<td>Isometric</td>
<td>27.3 cm.</td>
<td>27.1 cm.</td>
<td>26.9 cm.</td>
<td>26.9 cm.</td>
<td>-.4 cm.</td>
</tr>
<tr>
<td></td>
<td>Static</td>
<td>27.4 cm.</td>
<td>27.1 cm.</td>
<td>26.9 cm.</td>
<td>26.9 cm.</td>
<td>-.5 cm.</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>27.7 cm.</td>
<td>27.3 cm.</td>
<td>27.2 cm.</td>
<td>27.2 cm.</td>
<td>-.5 cm.</td>
</tr>
<tr>
<td>Biceps Girth</td>
<td>Autosuggestion</td>
<td>30.2 cm.</td>
<td>29.7 cm.</td>
<td>29.5 cm.</td>
<td>29.5 cm.</td>
<td>-.7 cm.</td>
</tr>
<tr>
<td></td>
<td>Isometric</td>
<td>31.3 cm.</td>
<td>31.0 cm.</td>
<td>30.4 cm.</td>
<td>30.4 cm.</td>
<td>-.9 cm.</td>
</tr>
<tr>
<td></td>
<td>Static</td>
<td>31.5 cm.</td>
<td>30.7 cm.</td>
<td>30.5 cm.</td>
<td>30.5 cm.</td>
<td>1.0 cm.</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>32.5 cm.</td>
<td>32.2 cm.</td>
<td>31.7 cm.</td>
<td>31.7 cm.</td>
<td>-.8 cm.</td>
</tr>
</tbody>
</table>
APPENDIX F

COMPUTATION OF DUNCAN’S NEW MULTIPLE RANGE TEST
FOR UNEQUAL GROUPS FOR ELBOW FLEXION
STRENGTH OF PREFERRED ARM

<table>
<thead>
<tr>
<th></th>
<th>df</th>
<th>S. S.</th>
<th>M. S.</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>44</td>
<td>867</td>
<td>125.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between</td>
<td>2</td>
<td>226</td>
<td>113</td>
<td>7.2</td>
<td>.01</td>
</tr>
<tr>
<td>Within</td>
<td>42</td>
<td>641</td>
<td>15.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ F = \frac{M.S.}{\text{between groups}} \]
\[ F = \frac{113}{15.2} = 7.2 \]

F = F ratio \hspace{1cm} M.S. = Mean Square between group means
\hspace{1cm} 02 = Mean Square Within Groups

<table>
<thead>
<tr>
<th>Group B</th>
<th>Group C</th>
<th>Exercise Group A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isometric Exercise</td>
<td>Static Exercise</td>
<td>Autosuggestion</td>
</tr>
<tr>
<td>Mean Gain</td>
<td>8.2 lbs.</td>
<td>4.7 lbs.</td>
</tr>
<tr>
<td>Number of Subjects</td>
<td>14</td>
<td>13</td>
</tr>
</tbody>
</table>

\[ Z = \frac{\overline{B} - \overline{A}}{\sqrt{\frac{2(N_b)(N_a)}{N_b - N_a}}} \]
\[ Z = \frac{8.2 - 2.9}{\sqrt{\frac{2(14)(18)}{14 - 18}}} \]
\[ Z = 20.9 \hspace{1cm} \text{Isometric exercise strength gain is significantly greater than} \]
\hspace{1cm} \text{autosuggestion exercise strength gains at the 1 per cent level.} \]

\[ Z = \frac{\overline{B} - \overline{C}}{\sqrt{\frac{2(N_b)(N_c)}{N_b - N_c}}} \]
\[ Z = \frac{8.2 - 4.7}{\sqrt{\frac{2(14)(13)}{14 - 13}}} \]
\[ Z = 12.8 \hspace{1cm} \text{Isometric exercise strength gain is significantly greater} \]
\hspace{1cm} \text{than static exercise strength gain at the 5 per cent level.} \]
APPENDIX F (CONTINUED)

\[ Z = C - \bar{X} \sqrt{\frac{2 \left( N_c \right) \left( N_a \right)}{N_c - N_a}} \]

\[ Z = 4.7 - 2.9 \sqrt{\frac{2 \left( 13 \right) \left( 18 \right)}{13 - .18}} \]

\[ Z = 6.98 \quad \text{No significant difference exists at the 1 per cent level between static exercise strength gains and autosuggestion exercise strength gains.} \]
VITA

The author was born in Empire, Louisiana on February 9, 1936. He received his elementary and high school education in Buras, Louisiana where he graduated in 1954 from Buras High School.

In 1958 he received his Bachelor of Science degree from the University of Southwestern Louisiana. Upon graduation he served as a graduate assistant at the University of Maryland. His Master of Arts degree was acquired there in 1960, his major being physical education and his minor, health.

He began his doctoral work at Louisiana State University in 1961 and served as a graduate assistant there for one semester. The Doctor of Philosophy degree was awarded him in June, 1964. He majored in physical education and minored in psychology.

The author has taught in public and private schools in and around Baltimore County, Maryland and is presently an assistant professor of physical education at the University of Southwestern Louisiana.

He is a member of the Louisiana Association of Health, Physical Education, and Recreation; the American Association of Health, Physical Education, and Recreation; Phi Epsilon Kappa, and Phi Kappa Phi.

The author has been published in The Research Quarterly and The Physical Educator.
Candidate: Louis Elmo Bowers

Major Field: Physical Education


Approved:

[Signatures]

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination: April 29, 1964