EFFECTS OF ARM STRENGTH DEVELOPMENT PROGRAMS

ON SWIMMING SPEED

by

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A THESIS

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EFFECTS OF ARM STRENGTH DEVELOPMENT PROGRAMS ON SWIMMING SPEED

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by

Robert Ruckert

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ABSTRACT

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Purpose

The purpose of this investigation was to determine the effectiveness of two methods of resistive exercises in the development of muscular strength and to determine whether increased muscular strength improved swimming speed.

Methods

Fifty-one college men enrolled in three intermediate swimming classes at Sam Houston State University were assigned to one of three groups. Group I participated in an exer-genie training program and a swimming training program. Group II participated in a swimming training program only. Group III served as a control group, participating in a regular intermediate swimming class. The subjects participated in the training programs three days per week for nine weeks.

The exer-genie training program included both isometric and isotonic contractions. The subject exerted three 6-second maximum isometric contractions either before or during the isotonic movements against an immovable resistance provided by the exer-genie. The progressive resistive procedure was followed in executing isotonic

contractions. The subject exerted maximum effort against the exergenie at a moderate rate of speed through a complete range of motion. All exercise movements were performed with a resistance that could be moved only three times through the specified range of motion. The 6-second isometric contraction was performed at a specified position during this isotonic movement. The exercises used to achieve the isometric and isotonic contractions were the curl, bench press, and straight arm pull. Each exercise was executed for one set with a maximal load for three repetitions.

The swimming training program consisted of swimming the following routine: (1) eight 25-yard sprints at full speed, using the American crawl only, and (2) arm pull for 100 yards, using no leg kick.

Isometric and isotonic strength tests were administered to all the subjects before and after the nine week training program. Isometric strength was measured by the aircraft cable tensiometer, and the 1 RM was used to measure isotonic strength. Both the isometric and isotonic strength tests measured (1) forearm flexion and (2) arm flexion and forearm extension. The swimming speed test was also administered to all the subjects before and after the training period. Each subject, using only his arms, was timed for a 30-yard sprint swim.

The comparison of group average pretest and group average posttest scores of the swimming speed test, the isotonic strength test, and the isometric strength test provided the statistical data that

was analyzed. The pairing design t-test was used to determine significant differences between group average pretest scores and group average posttest scores of each group. Scores that were significant in the pairing design t-test were examined by the Newman-Keuls multiple-range test, which provided a sequential method of examining all differences between pairs of group means.

Findings

1. A combination of the exer-genie training program and the swimming training program improved swimming speed, whereas the swimming training program alone did not improve swimming speed.

2. A combination of the exer-genie training program and the swimming training program increased isometric strength for arm flexion, whereas the swimming training program alone did not increase isometric strength for arm flexion.

3. A combination of the exer-genie training program and the swimming training program did not increase isometric strength for forearm extension and arm flexion more than did the swimming training program alone.

4. A combination of the exer-genie training program and the swimming training program increased isotonic strength for (1) forearm extension and arm flexion and (2) forearm flexion more than did the swimming training program alone, but the increases were not statistically higher.

5. A combination of the exer-genie training program and the swimming training program as well as the swimming training program alone were equally effective in the development of isotonic and isometric strength for forearm extension and arm flexion.

6. A combination of the exer-genie training program and the swimming training program as well as the swimming training program alone produced a greater increase in isotonic strength than in isometric strength for forearm flexion.

Dr. Harold J. Fischer
Supervising Professor

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R. R.

Sam Houston State University

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CHAPTER I

INTRODUCTION

Statement of the Problem

Limited research has been done on methods of weight training as a means of improving swimming speed. Studies using the exer-genie to improve muscular strength are rare. The problem with which this study deals is two-fold: (1) to determine whether strength is increased through the use of the exer-genie, and, if so, (2) to determine whether increased muscular strength increases swimming speed.

In 1955 Davis concluded that swimming speed was increased in the 25-yard and 50-yard swim after a weight training program.[1] However, Thompson and Stull reported in 1959 that there were no significant gains in the 30-yard swim after six weeks of weight training.[2] In 1960 Nunney found that circuit exercises plus swimming increased swimming speed more than did swimming alone.[3] From an investigation in 1963, Jensen concluded that no one of five combinations of weight

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[1] Jack F. Davis, "The Effect of Weight Training on Speed in Swimming," The Physical Educator, 12:28-29, March, 1955.

[2] G. Alan Stull and Hugh L. Thompson, "Effects of Various Training Programs on Speed of Swimming," Research Quarterly, 30:479-85, December, 1959.

[3] Derek N. Nunney, "Relation of Circuit Training to Swimming," Research Quarterly, 31:188-98, May, 1960.

lifting and swimming programs was superior to the other combinations in developing swimming speed.[4]

Purpose

The purpose of this investigation is to determine the effectiveness of two methods of resistive exercises in the development of muscular strength and to determine whether increased muscular strength improves swimming speed. The exer-genie combines both methods of resistive exercises. The two methods of resistive exercises are:

1. Isometric method. A maximum contraction is exerted for 6 seconds within the isotonic exercise against a resistance that does not allow movement.

2. Isotonic method. A pre-set resistance is moved through a complete range of motion except for the 6 second isometric contraction.

Definition of Terms

Extensors are muscles that straighten or extend (moving bones apart) as in the hand moving away from the shoulder.

Flexors are muscles that bend or contract (bringing bones together) as in the case of the elbow joint when the hand is being drawn to the shoulder.

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[4]Clayne R. Jensen, "Effects of Five Training Combinations of Swimming and Weight Training on Swimming the Front Crawl," Research Quarterly, 34:471-77, December, 1963.

Isometric contraction is the development of tension without change in the length of muscles, such as occurring in antagonistic muscles during static contraction.

Isotonic contraction is muscle shortening during contraction, while the load remains the same. In practice, however, this concept is frequently violated, and any contraction involving shortening of the muscle may be called isotonic.

Load is the actual poundage lifted during a weight training exercise.

Muscle is an organ or tissue that is capable of contracting to produce movement of the body or of parts of the body. It is a machine that converts chemical energy into mechanical work or tension. Muscles are classified according to their structure and function:

(1) Smooth muscles are non-striated muscles. They are involuntary muscles found in the digestive or urinary tracts.

(2) Striated muscles are voluntarily controlled skeletal muscles. They are striated muscles which are attached to the skeleton. A response makes them function.

(3) Cardiac muscles are found only in the heart. Their action is involuntary, automatic, and rhythmic.

Muscular strength is the amount of force which can be exerted by a particular muscle while contracting.

Overload is any work which is more intense than usual.

Repetition of a weight training exercise is executed each time a complete movement is performed.

1 RM is one repetition with maximum weight.

Set refers to the number of times that a fixed number of repetitions of an exercise are performed.

Static contraction is a contraction in which the muscle does not shorten or lengthen.

Procedure

The subjects for this research consisted of college men enrolled in required physical education classes at Sam Houston State University. Three intermediate swimming classes composed the three different groups: One class was designated as Group I; another, Group II; and the other, Group III. Group I participated in the exer-genie training program and the swimming training program. Group II participated in the swimming training program only. Group III served as a control group, participating in a regular intermediate swimming class.

The exer-genie training program included both isometric and isotonic contractions. In the isometric method the subjects exerted a maximum contraction for 6 seconds against a resistance not allowing movement. Each exercise was performed at specific positions, either before or during the isotonic movement, with three 6-second maximal contractions. In the isotonic method the subjects executed each exercise with a pre-set resistance that could be moved only three times through the specified range of motion. The 6-second isometric contraction

was performed at a specified position during this isotonic movement. When the subject was able to move this maximum pre-set resistance through the complete range of motion more than three repetitions, additional poundage was added.

Each subject was measured for both isometric and isotonic strength. The aircraft cable tensiometer was used to measure isometric strength. Strength tests, adapted from methods developed by H. Harrison Clarke, for this instrument were utilized. The aircraft cable tensiometer measures strength of muscles being tested by indicating tension on the cable. This tension may be converted directly into pounds from a calibration chart. The calibration chart has been validated and accompanies the tensiometer.[5] Isotonic strength was measured by the 1 RM (one repetition maximum). In this testing procedure weight was either added or removed until one repetition with maximum weight could be done. The subject was required to complete a full range of motion for a specific testing position. Both tests measured the strength of the muscles involved in (1) forearm flexion and (2) forearm extension and arm flexion.

The swimming training program consisted of swimming sprints and distances. The subjects were also taught the proper way of swimming various strokes. Form and grace of movement, as well as speed, were

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[5] H. Harrison Clarke, Cable-Tension Strength Tests, (Chicopee, Massachusetts, Brown-Murphy Co., 1953), p. 2.

developed through this routine. The swimming speed test was administered to measure swimming speed for 30 yards. Subjects were required to use only their arms in this sprint swim.

The subjects in Groups I and II participated in the training programs three times per week for a period of nine weeks. Both exercise groups followed a training program designed to develop upper body and limb muscles used in swimming. In the isotonic and isometric program for Group I, all exercises were performed for one set with a maximal load for three repetitions. The exercises, together with the muscle groups that each was designed to develop, are as follows:

1. Curl -- forearm flexors.
2. Bench Press -- forearm extensors and arm flexors.
3. Straight Arm Pull -- arm extensors and latissimus dorsi.

CHAPTER II

REVIEW OF RELATED LITERATURE

Present day success or failure of competitive athletics is determined to a great extent by its training programs. It is generally agreed that strength is essential for successful performance in athletics. Training programs designed specifically for strength gains are used widely in athletics today. Much research has been done on methods of resistive exercises which are used in various training programs. The methods of resistive exercise most commonly used to increase strength are the isotonic and isometric methods.

Scientific Basis of Strength Development

Through laboratory experimentation in 1897, Morpurgo determined that a muscle increased in size and strength by increasing the size of its muscle fibers. His experimentation compared the cross section of the sartorius muscle of two dogs. The sartorius muscle was removed before the exercise and compared with those taken out after the exercise. For two months the dogs were trained by vigorous running in an exercise wheel. One dog ran 3218 km; and the other, 1550 km. Increases in the sartorius cross section were 53 per cent and 55 per cent respectively. Muscle fibers did not increase in number. In a similar experiment with rats, Morpurgo determined that exercise did

not increase the length of muscle fibers.[6]

Roux posed that increases in hypertrophy and strength were developed not only by exercise, but by specific types of exercise. Lange, a student of Roux, stated that muscles gain in strength only when the greatest power of the muscle is used. Muscles must be able to do more work in a shorter period of time.[7]

In 1926 Petow and Siebert restated the Roux-Lange overload theory. They provided actual evidence of the overload theory through experimentation with littermate rats. Twenty-one rats were divided into three equal groups. Group A was a control group which did no exercise. Groups B and C ran at various rates of speed. The hearts and leg muscles were weighed before and after the experiment. Groups B and C showed increases in heart and leg muscle weights, whereas Group A showed no increase in weight. In another experiment the heart and gastrocnemius weights were compared in three groups of littermate rats. The three groups of rats ran various distances at the same speed. Group A ran a total of 57.6 km by running one hour

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[6]B. Morpurgo, "Uber Activitats-Hypertrophie der Wilkurlichen Muskeln," Virchow's Archives of Pathological Anatomy, 150:522-44, 1897, cited by Arthur H. Steinhaus, "Strength from Morpurgo to Muller--A Half Century of Research," Journal of the Association for Physical and Mental Rehabilitation, 9:147-50, September-October, 1955.

[7]Lange, Uber Funktionelle Anpassung USW (Berlin: Julius Springer, 1917, cited by Arthur H. Steinhaus, "Strength from Morpurgo to Muller--A Half Century of Research," Journal of the Association for Physical and Mental Rehabilitation, 9:147-50, September-October, 1955.

per day for three months. Group B ran 172.8 km totally by running three hours per day for three months. Running three hours per day for six months, Group C ran a total of 345.6 km. No one group showed an increase in heart weight, but Group B showed a slight increase in gastrocnemius weight over the other two groups.[8]

In a third experiment Siebert stimulated the gastrocnemius muscles of seven frogs. One leg of each of the frogs was tied to prevent movement; the other leg was loose, allowing movement. The muscles of both legs were stimulated with currents of the same intensity. There was a three-second stimulation followed by a three-second rest period for a total of twenty minutes per day for fourteen days. The gastrocnemius muscles that were tied weighed a mean of 13 per cent more than those of the opposite leg.[9] Through the preceding experiments Petow and Siebert further validated the Roux-Lange theory that muscular hypertrophy results in proportion to the amount of work performed and that hypertrophy results only when the muscle is overloaded.[10]

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[8]H. Petow and W. Siebert, "Studien uber Arbeitenhypertrophy des Muskela," Z. Klin Med., 102:427-33, 1925, cited by Arthur H. Steinhaus, "Strength from Morpurgo to Muller--A Half Century of Research," Journal of the Association for Physical and Mental Rehabilitation, 9:147-150, September-October, 1955.

[9]Werner W. Siebert, "Untersuchungen uber Hypertrophie des Skelletmuskels," Zeitschrift fur klinische Medizin, 109:350-59, 1928, cited by Arthur H. Steinhaus, "Strength from Morpurgo to Muller--A Half Century of Research," Journal of the Association for Physical and Mental Rehabilitation, 9:147:50, September-October, 1955.

[10]Lange, *loc. cit.*

Isotonic Method

In 1945 DeLorme devised a system of heavy resistive exercises widely utilized in athletics, physical education, and physical therapy. Today, most conditioning programs employing weight training exercises are based on DeLorme's procedures. His method for developing muscle power by exercise was founded on the principle of heavy resistance and low repetition exercises. In this method, the overload principle, heavy resistance requiring near-maximum strength of the muscle was used. Recognizing also the importance of developing endurance along with strength, DeLorme differentiated between endurance-building and power-building exercises. Endurance-building exercises employ low resistance for a large number of repetitions; whereas power-building exercises call for heavy resistance for a low number of repetitions. Each type of exercise produces its own results.[11]

Upholding DeLorme's theory, Counsilman reported in 1955 that no single type of exercise was capable of developing both strength and endurance. Any training or developmental program should include heavy resistive exercises and also exercises that develop endurance.[12] He also reported that working with near-maximum loads most rapidly

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[11] T. L. DeLorme, "Heavy Resistance Exercises," Archives of Physical Medicine, 27:607-30, October, 1946.

[12] James E. Counsilman, "Does Weight Training Belong in the Program?" Journal of Health, Physical Education, Recreation, 26: 17-18, January, 1955.

increases the size and strength of muscles. Since strength and endurance are desirable qualities to develop in all activities, all training programs should be designed to build these qualities.[13]

In 1945 DeLorme accumulated information from clinical observations of 300 adult males at Gardiner General Hospital in Chicago, Illinois. Although the exercises employed were for developing the quadriceps muscles, DeLorme, using the same principle, prescribed exercises for other muscle groups. Leg flexion and extension were the exercises used to develop increased muscle power in the quadriceps muscle. With a 5-pound boot strapped to his foot and with his knee flexed at a 90 degree angle, the patient extended his leg to a 180 degree angle and then lowered it to the starting position. This exercise was repeated ten times to determine the amount of weight to be used the first week. The weight to be used daily for the rest of the week was determined by increasing the resistance 1¼ to 5 pounds at a time to a maximum weight that could be lifted for 10 RM. Every Friday the patients attempted to lift increased resistance which was used for the 10 RM the next week. The patients performed 70 to 100 repetitions for 30 minutes a day, five days per week. After the 10 RM was determined each Friday, additional weight was added until the patients could achieve their 1 RM. The 1 RM was performed only once

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[13] James E. Counsilman, "Physiological Effects of Training," Athletic Journal, 35:14-16, February, 1955.

a week. DeLorme concluded that to develop muscle power by exercise, heavy resistance and low repetition at regular intervals were necessary. Endurance, he contended, was produced by exercises with low resistance and high repetition.[14]

The original DeLorme procedure required seven to ten bouts of repetitive exercise. Daily the subjects attempted to increase the stress load to the maximum so that less time each day was devoted to warm-up contractions. Each week maximal resistance was increased. After further experience DeLorme and Watkins reported in 1948 that two or three bouts of exercise were more beneficial than the original seven to ten and that only one bout should call forth maximal effort. Adjustment of the resistance to 50 percent of the maximum on the first bout, 75 per cent of the full load on the second bout, and 100 per cent on the third bout was recommended. By this modification two-thirds of the daily work session was devoted to "warm-up" activity, and the amount of overload exercise was reduced to ten repetitive contractions.[15]

Between 1950 and 1954 Hellebrandt and Houtz conducted 620 experiments, observing seventeen subjects in seven different muscle

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[14] T. L. DeLorme, "Restoration of Muscle Power by Heavy Resistance Exercises," Journal of Bone and Joint Surgery, 27:645-67, October, 1945.

[15] T. L. DeLorme and Arthur L. Watkins, Progressive Resistance Exercise Technic and Medical Application (New York:Appleton-Century Crofts, Inc., 1951).

training procedures. The investigators observed the wrist flexor and extensor muscles. All exercise was repetitive and was performed on the Kelso-Hellebrandt modification of the Mosso ergograph. At a uniform cadence all exercise was performed to the rhythm of an audio-visual metronome. The work assignment was divided into bouts of 25 lifts, and each bout was followed by a rest period equal in time to the exercise period. The number of bouts executed by the individuals was determined by the degree of overloading. A uniform relationship between the work intensity and muscular strength was revealed by these investigations. Improvement was minimal in the underload bouts, but it became more intense with optimal resistance. Two hundred and fifty contractions per day three times a week for eight weeks produced only a minimal increase in strength when the resistance load fell in the underload zone. Executed against moderate overloading, the same number of contractions produced a dramatic gain in functional capacity. Conclusions drawn by these investigations were that repetitive exercise performed against heavy resistance produced an increase in strength and endurance.[16]

A study was made in 1950 by Capen to determine the effects of systematic weight training on power, strength, and endurance. Two

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[16]F. A. Hellebrandt and Sara Jane Houtz, "Mechanism of Muscle Training in Man: Experimental Demonstration of the Overload Principle," Physical Therapy Review, 36:371-83, June, 1956.

groups of students were utilized in this study. One group was a weight training class of 43 sophomore men, and the other group was a conditioning class of 29 freshmen men. The weight lifting class periods were devoted entirely to weight training exercises, and the conditioning group devoted class time to a vigorous conditioning program. Both groups met twice a week for eleven weeks and were tested before and after the training program. Muscular strength was measured by McCloy's Strength Test for right grip, left grip, leg lift, back lift, chinning, and dipping on parallel bars. Sit-ups, push-ups, squat jumps, and chinning were measures of endurance. To measure circulo-respiratory endurance, the subjects ran the 300-yard shuttle run. To measure athletic power, the subjects performed the standing broad jump, standing Sargent Jump, and the running Sargent Jump and putted an 8-pound shot. After the eleven-week training program the weight training group had improved significantly in muscular strength and power as compared to the conditioning group. The two groups showed no significant differences in increases in muscular endurance or circulo-respiratory endurance. Although the conditioning group had higher initial test averages, the weight lifting group improved more significantly in power events.[17]

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[17]Edward K. Capen, "The Effect of Systematic Weight Training on Power, Strength, and Endurance," Research Quarterly, 21:83-93, May, 1950.

Sixty-nine male college students in regular physical education classes were utilized by Masley, Hairabedian, and Donaldson in a study in 1953 of weight training in relation to strength, speed, and endurance. The subjects were divided into three groups: weight training, volleyball, and lecture class. The weight training group executed standard progressive resistive exercises, and the volleyball group participated in a regular physical education volleyball class. No physical activity was performed by the lecture class. These groups met three times a week for eight weeks and were tested before and after the eight-week period. Strength scores were obtained by McCloy's revision of the Roger's Strength Index. Twenty-four rotary movements of a 9-inch handle in a frontal plane measured speed of movement. To measure coordination, the subjects attempted 50 fencing lunges at a 2-inch copper disc recessed in front and overhead targets. The score for this coordination test was assessed by the number of hits divided by the total elapsed time. At the end of the eight-week training period, significant gains in strength and coordination were shown by both the weight lifting and volleyball groups. A significant gain in speed of movement was shown only by the weight lifting group. Compared to the volleyball and lecture classes, the weight lifting class increased more in speed, strength, and endurance.[18]

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[18]John W. Masley, Ara Hairabedian, and Donald N. Donaldson, "Weight Training in Relation to Strength, Speed, and Coordination," Research Quarterly, 24:308-15, October, 1953.

To test the hypothesis that a program of weight training will increase an athlete's leg strength and power, Brown and Riley conducted a study in 1957, utilizing forty freshmen basketball players from Springfield College. Roger's Physical Fitness Index test was used to divide the subjects into two groups. One group participated in a weight training program; the other group participated in the regular basketball practice sessions. Exercising three days per week for five weeks, the subjects in the weight training program performed two sets of ten repetitions of heel raising exercises and a third set of as many repetitions as possible. The initial weight that could be lifted was determined by the ankle plantar flexion test, and increased weight as prescribed was added. The weight training group was tested at the beginning and every Friday of the training period; the control group was tested at the beginning and end of the weight training program. The vertical jump was measured by the Sargent Jump Test, and a leg-lift strength test administered on a dynamometer measured strength of the knee extensor muscles. Results of this experiment indicated that both groups showed an increase in vertical jumping, but the increase shown by the weight lifting group was statistically significant. The weight training group showed a significant increase in leg-lift strength; whereas the control group showed a decrease.[19]

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[19]Robert J. Brown and Douglas R. Riley, "Effects of Weight Training on Leg Strength and Vertical Jump," Scholastic Coach, 27:44-47, December, 1957.

A study was conducted by Berger in 1962 to determine the optimum number of repetitions to employ in training for the quickest development of strength. At the beginning and end of the twelve-week training period, 199 freshmen and sophomore male students' maximum strength was determined by the 1 RM on the bench press. The subjects trained three days a week. In the training program each of the six groups of students performed a different number of repetitions per set. The programs were 2 RM, 4 RM, 6 RM, 8 RM, and 12 RM. Berger concluded from the results of this study that strength was developed more quickly when between three and nine repetitions per set were employed in the training program.[20]

Berger conducted a study in 1965 to determine which proportions of maximum dynamic strength used in training were as effective for increasing strength as training with the 1 RM. The subjects for this study were 79 male college students enrolled in weight training courses at Texas Tech University. All the subjects followed a 3-week training program concerned only with increasing leg strength. Following this first phase, the subjects were assigned by random number to one of seven weight training programs for 6 weeks. All subjects were tested for 1 RM deep knee bend before and after each phase. Determination of the 1 RM deep knee bend was similar for all subjects. The load was

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[20]Richard A. Berger, "Optimum Repetitions for the Development of Strength," Research Quarterly, 33:334-38, October, 1962.

increased by 10 pounds after each single lift until the 1 RM was reached. During the first three weeks of training the subjects performed one set of deep knee bends with a 6 RM load, three times a week. The seven weight training programs were as follows: Groups I, II, and III performed one repetition with 66, 80, and 90 per cent, respectively, of the 1 RM at each of two weekly training sessions. The third training session of the week was used to determine the 1 RM. Group IV performed one repetition with the 1 RM three times a week at the training sessions, and the new 1 RM was determined once a week during a training session. Group V performed one repetition with 66 per cent of the 1 RM at each of three weekly sessions. At three weeks and six weeks the 1 RM was determined. Group VI trained once a week and the 1 RM was determined at this time. Group VII was tested for 1 RM before and after six weeks but did not perform any leg exercises. From the results of this study, Berger concluded that two weeks of training twice weekly with two-thirds or more of the 1 RM will significantly increase strength if at least one weekly maximum isotonic effort is performed. Strength was not increased in 6 weeks by training with two-thirds of the 1 RM for one set, three times a week.[21]

Berger and Hardage conducted a study in 1967 to determine whether weight training with maximum loads for each of ten repetitions of a

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[21]Richard A Berger, "Comparison of the Effect of Various Weight Training Loads on Strength," Research Quarterly, 36:141-46, May, 1965.

set was more effective for increasing strength than performing ten repetitions with the 10 RM load. Fifty male college students at Texas Tech University were assigned to one of two experimental groups and trained for one set each session, three times a week for 8 weeks. One group performed 10 repetitions with the 10 RM for one set. The other group performed 10 repetitions for one set; each repetition was performed at maximum or near maximum effort. Beginning with the 1 RM load for the first repetition, the loads at each repetition were gradually reduced commensurate to the subject's strength and fatigue. The Universal Gym was used for training and testing. The subjects were tested for 1 RM bench press strength before and after the 8-week training period. The load increments began at 10 pounds and were reduced to 5 pounds when the 1 RM was reached. From the results of this study, Berger and Hardage concluded that weight training with maximum or near maximum loads for each of 10 repetitions of a set was more effective for increasing strength than a program of performing 10 repetitions with the 10 RM load.[22]

O'Shea conducted a study in 1969 to determine the most effective method of weight training for the development of muscular strength and endurance required for 400-meter running. From an intermediate

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[22]Richard A. Berger and Billy Hardage, "Effect of Maximum Loads for Each of Ten Repetitions on Strength Improvement," Research Quarterly, 38:715-18, December, 1967.

weight training class at Oregon State University, thirty students were selected randomly to participate in this study. The subjects participated in a conditioning program for two weeks and then were randomly assigned to specific groups for the 8-week test period. Executing the bench press, seated dumbbell curl, and squat, the subjects used maximum loads for designated numbers of repetitions and sets. The subjects were assigned to one of three groups. The training program of Group A, generally considered to be for strength, consisted of four sets of 4-5 repetitions. The training programs of Group B, a combination of strength and muscular endurance, consisted of four sets of 9-10 repetitions. Considered to be a program for endurance, the training program for Group C consisted of four sets of 14-15 repetitions. The subjects followed their respective programs on Mondays and Fridays, and on Wednesdays they were subjected to progress evaluation, light training, and a 400-meter run. Each Monday five and ten pounds, respectively, were added to the weight loads for the bench press and squat. If the subjects could not lift this new weight, the load was reduced to the weight lifted in the previous workout. To measure cardiovascular endurance, the Astrand Estimated Uptake Test for the 400-meter run was used. The 400-meter run was used to determine muscular endurance. The 1 RM in the bench press and squat and the ability to increase the weight load weekly were used to determine dynamic strength. The results of this study indicated that all three weight programs were equally effective in

increasing muscular strength and muscular endurance for 400-meter running. O'Shea concluded that any method of short term progressive weight training for large muscle groups is effective in improving 400-meter running performance.[23]

To determine whether high intensity, low-repetition training increased strength and altered fatigue resistance, Stull and Clarke conducted a study in 1970, utilizing 20 male college freshmen and sophomores. Training three times a week for 6 weeks, the subjects performed three sets of curls with the preferred arm during each session. The first set of exercises consisted of ten repetitions against 50 per cent of the subject's 10 RM; the second set, ten repetitions at 75 per cent of the 10 RM; and the third set, ten repetitions at 100 per cent of the 10 RM. Upon successful completion of 15 repetitions against the previous 10 RM, five additional pounds of resistance was added and then used as the new 10 RM. Before and after the 6-week training period, the subjects were tested in a 5-minute bout of rhythmic exercise involving the elbow flexors. The subjects exerted 150 maximal contractions at 1-second intervals. A canvas belt was placed over the subject's mid-arm and attached to a Baldwin-Lima-Hamilton SR-4 load cell. As the subject contracted, the force was received by the load cell, converted to electrical

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[23]John P. O'Shea, "Effects of Varied Short Term Weight Training Programs on Improving Performance in the 400-Meter Run," Research Quarterly, 40:248-50, March, 1969.

energy, and transmitted to a Beckman Type RS dynograph, which amplified the voltage and recorded it graphically. At the end of the 6-week training period, the subjects showed an increase in muscular strength and absolute endurance, but fatigable work was not altered.[24]

In 1970 Withers conducted a study to determine which combination of repetitions and groups of repetitions in a weight training program produced statistically significant gains of strength over all other combinations. The subjects consisted of 55 male freshmen who were enrolled in two weight training classes at Washington State University. These subjects were randomly chosen and randomly assigned to one of three groups. Using various combinations of sets and repetitions in the curl, bench press, and squat, the subjects within each group trained as follows: Group A, 3 X 7 MR; Group B, 4 X 5 MR; and Group C, 5 X 3 MR. The training programs were performed two times per week for nine weeks. The progressive resistance method was used for the nine-week training period in all three groups. Weight was added to the barbell whenever the subject was able to perform more than his designated number of repetitions. The 1 MR was used to measure isotonic strength. The subjects were pretested and posttested for each of the three lifts. A strength/weight ratio was derived by

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[24]G. Alan Stull and David H. Clarke, "High Resistance, Low-Repetition Training as a Determiner of Strength and Fatigability," Research Quarterly, 41:189-93, May, 1970.

adding the best lift of each exercise and dividing it by the body weight. These ratios for all three groups were compared. Within-group t-ratios showed that all three groups gained significantly in strength. An analysis of covariance established that no one group gained more significantly than the other groups. In conclusion, a progressive resistance method of weight training results in a statistically significant strength increase. It appears that training with 4 X 5 MR increases strength more, but not satistically more, than does training with 3 X 7 MR and 5 X 3 MR.[25]

Isometric Method

Current interest in isometric programs is primarily based upon studies conducted by Hettinger and Muller. In 1953 Hettinger and Muller conducted experiments to determine the most effective methods of increasing muscular strength and hypertrophy. They examined the effect of duration and frequency of various strength exercised upon the increase of maximal isometric power of contractions. Nine male subjects participated in 71 separate experiments over a period of eighteen months. All isometric training was done with a predetermined amount of tension measured by a spring scale. In these experiments the flexor and extensor muscles of the forearm at a 90-degree angle to the upper arm were used. Once a week maximal strength was measured

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[25]R. T. Withers, "Effect of Varied Weight Training Loads on the Strength of University Freshmen," Research Quarterly, 41:110-13, March, 1970.

by a dynamometer. Exercising five days per week, the subjects varied their programs according to intensity, duration, and frequency of contractions per day. The investigators found that there was an increase in strength when the resistance was about two-thirds of maximal strength and when the contraction was held for six seconds once a day.[26]

Reporting on a 1957 investigation on the physiology of muscular strength and training, Muller stated that the stimulus for increased muscular strength is provided by an increase in work intensity beyond that previously demanded of a muscle. He found that the training stimulus did not have to be a maximal strength contraction; about forty per cent of the maximal strength is just as beneficial as a longer sustained contraction. Another conclusion of this study was that contracting a muscle one time a day is just as beneficial as contracting it more than once a day.[27]

In 1956 Wolbers and Sills conducted a study of strength development by isometric contractions. Twenty high school boys served as subjects and were divided into an experimental group and a control group. To measure strength in the leg lift, back lift, and left and

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[26]Theodore Hettinger and E. A. Muller, "Muskelleistung und Muskel Training," Arbeitsphysiologie, 15:111-26, October, 1953.

[27]Erich A. Muller, "The Regulation of Muscular Strength," Journal of the Association for Physical and Mental Rehabilitation, 11:41-47, March-April, 1957.

right hand grip, a dynamometer was used. The experimental group executed a series of nine 6-second static exercise bouts daily for eight weeks. The subjects worked in pairs; one provided the resistance while the other exercised. Significant gains were made by the experimental group in the leg lift, back lift, and left and right grip. The findings of this study, that 6-second isometric contractions will cause gains in strength, supported the findings of Hettinger and Muller.[28]

Mathews and Kruse conducted an investigation in 1957 to determine the effects of different frequencies of isometric exercise on the forearm flexor muscle groups. Sixty male college students participated in the investigation. Clarke's Cable Tension Strength Test for the elbow flexor muscle group was used for both strength measurement and isometric exercise. The subjects exerted three consecutive 6-second maximal contractions on a strap against a cable tensiometer. The students were divided into four groups: Group I exercised twice a week; Group II, three times a week; Group III, four times a week; and Group IV, five times a week. At the end of the four-week training period, forty-four of the sixty students had shown a gain in strength. As the frequency of exercise increased, there was also an increase in the number of subjects who gained in strength.[29]

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[28]Charles P. Wolbers and Frank D. Sills, "Development of Strength in High School Boys by Static Muscle Contractions," Research Quarterly, 27:446-50, December, 1956.

[29]D. K. Mathews and Robert Kruse, "Effects of Isometric and Isotonic Exercise on Elbow Flexor Muscle Groups," Research Quarterly, 28: 26-37, March, 1957.

In 1958 Lawther made a comparison of the effectiveness of various methods of strength development. Sixty college men, divided into various experimental groups and one control group, were tested for static strength of dorsal flexion of the right wrist and outward rotation of the right hip. One experimental group executed a maximum pull for six seconds; another group held a maximum pull for twelve seconds. A third group executed a two-thirds maximum pull held for six seconds, and the other group held a two-thirds maximum pull for twelve seconds. The exercises used in testing were the same as those performed in the training programs. Although all of the training methods, except for the method involving a two-thirds maximum pull for twelve seconds, produced more significant improvement than did the control group, no one of the four training methods was significantly superior to any of the others for increasing contractile strength in the muscles involved in this experiment.[30]

Frequency and intensity of isometric contractions in developing muscular strength were observed by Rarick and Larsen in 1958. On the basis of initial strength scores, thirty post-pubescent boys from the eleventh and twelfth grades were divided into two experimental groups

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[30] J. D. Lawther, "The Pennsylvania State University Studies on Strength Development, Maintenance and Related Aspects," 61st Annual Proceedings, College Physical Education Association, 1958, pp. 142-9.

and one control group. Wrist flexion strength of the right hand was measured by a cable tensiometer. One experimental group held two-thirds maximum tension for six seconds once a day, Monday through Thursday. Every Monday the other experimental group performed five 6-second bouts of 80 per cent of maximum tension. The number of bouts was increased daily until a maximum of eight could be performed on Thursday. On Friday the subjects were tested to determine the amount of tension to be used the next week. At the end of the second, fourth, and eighth weeks, the strength test for wrist flexion was administered to all the subjects. Strength scores were significantly higher for the two experimental groups than for the control group at the end of the fourth training week, but there was no significant difference between the strength scores of the two experimental groups.[31]

Rarick and Larsen conducted another study in 1959 to determine the effect of variations in exercise frequency and intensity on muscular strength. Nine prepubescent males with a mean age of 12.5 years were divided into two experimental groups and one control group. The study compared an exercise program using a single daily 6-second contraction performed at two-thirds maximum tension with a program

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[31]G. Lawrence Rarick and Gene L. Larsen, "Observations on Frequency and Intensity of Isometric Muscular Effort in Developing Static Muscular Strength in Post-Pubescent Males," Research Quarterly, 29:333-41, October, 1958.

involving four to six contractions daily at 80 per cent maximum tension. Results of this study indicated that although both experimental programs resulted in a significant strength increase over the control group, the difference in strength gain between the two experimental groups was not significant.[32]

Wickstrom in 1958 conducted a study to determine whether significant improvement in grip strength was produced by a daily, single maximum isometric contraction. Twenty men and six women, all graduate students, were measured for grip strength of both hands by a Medart hand dynamometer. Using a medical cable tensiometer, the subjects exerted two-second maximum contractions daily, five days per week for six weeks. The grip strength of both hands was measured at the outset, at the end of three weeks, and at the end of six weeks. After both the three weeks and six weeks training periods, there was a loss in strength for both hands for the women. Except for a slight increase in right hand strength after three weeks, the men also showed a decrease in strength. Wickstrom concluded from the results of this experiment that grip strength was not significantly improved by a single maximum contraction daily.[33]

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[32]G. L. Rarick and G. L. Larsen, "The Effect of Variations in the Intensity and Frequency of Isometric Muscular Effort on the Static Muscular Strength in Pre-Pubescent Males," Arbeitsphysiologie, 18:13-21, September, 1959.

[33]Ralph L. Wickstrom, "An Observation on Isometric Contractions as a Training Technique," Journal of the Association for Physical and Mental Rehabilitation, 12:162, 166, September-October, 1958.

In 1962 Gardner conducted a study to determine (a) the extent to which scores for knee extension would be changed at points along the range of motion when the limb was exercised at only one point included in that range, and (b) the extent to which strength scores might be changed specifically on the non-exercised limb. Only the preferred leg was exercised. Strength scores were recorded only at the 115 degree, 135 degree, and 155 degree angles of knee extension for both the exercised and contralateral limbs. On the basis of strength scores obtained against a cable tensiometer at the three specified angles, sixty subjects were assigned to one of four groups. The subjects in Group I, the control group, were not assigned a training program. The other three experimental groups performed a 6-second isometric contraction held against two-thirds of their maximum tension loads, three times a week for six weeks. Group II exercised the preferred limb only at 115 degrees of knee extension; Group III, only at 135 degrees; and Group IV, only at 155 degrees. Before and after the 6-week experimental period all the subjects were tested for maximum isometric strength scores at all angles for both limbs. At the end of two and four weeks in the experimental period, the three experimental groups were also tested at their respective training angles on their exercised limbs so that a calculation of progressive two-thirds maximum loads could be made. The results of this study showed that all three experimental groups improved significantly in total strength (the sum of the scores of the three angles) for the

exercised limb, and Groups III and IV showed significant strength increases at their respective training angles. No group showed significant improvements for the exercised limb at angles other than the one for which it trained. For the unexercised limb there were no significant improvements in strength in any experimental group over the control group. In fact, compared to the control group, Groups II and IV showed a loss of mean strength in the unexercised limb. Gardner concluded that strength increases are quite specific to the area of exercise and that cross transfer of strength should not be expected to occur following isometric exercise.[34]

A study to determine whether isometric strength gains through the use of isometric training would improve performance of an explosive power movement was conducted by Ball, Rich, and Wallis in 1963. Sixty-three college men were divided into an experimental group and a control group on the basis of their abilities to exert isometric force against a vertical jump apparatus which was recorded by a back and leg strength dynamometer. This apparatus was used for measurement and training for isometric strength. Anthropometric measurements were made to insure that all subjects' knees were flexed at the same angle during the administration of the isometric strength test. The subjects

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[34]Gerald W. Gardner, "Specificity of Strength Changes of the Exercised and Nonexercised Limb Following Isometric Training," Research Quarterly, 34:98-101, March, 1963.

were tested for isometric strength and the vertical jump prior to and after the 6-week training period. The experimental group trained by exerting one 10-second maximum isometric effort three days per week. The same conditions as used for testing were followed during the training period. The control group did no training. Results showed that the experimental group gained significantly in isometric strength but not in the ability to perform the vertical jump. The control group did not gain in either isometric strength or in vertical jumping.[35]

A study was conducted by Cotten in 1967 to determine the relationship of the duration of sustained voluntary isometric contractions to changes in endurance and strength. The subjects for this investigation were 12 male and 12 female high school students enrolled in physical education classes at the University School of Florida State University. The subjects were randomly placed by lottery into four groups so that each group consisted of three boys and three girls. The four groups were assigned training percentages of 25, 50, 75, and 100 per cent of a maximum voluntary isometric contraction. Each subject's tension was computed by multiplying the group-assigned per centage by the isometric strength of each subject. Training at their

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[35]Jerry R. Ball, George Q. Rich, and Earl L. Wallis, "Effects of Isometric Training on Vertical Jumping," Research Quarterly, 35:231-35, October, 1964.

respective percentages, the subjects performed one sustained voluntary isometric contraction daily, five times a week. When its t-value was statistically significant at a minimum of .01 level, the group ceased training. The subjects were administered a strength test and an endurance test before and after the training period. The cable tensiometer measured strength by determining the maximum voluntary contraction of the left forearm flexors. The endurance test determined the amount of oxygen consumed per minute during sustained contractions at the prescribed tension. The 25, 50, and 75 per cent groups were tested at their respective contraction percentages, plus or minus five per cent. The 100 per cent group was tested at each of the four percent contractions. At his prescribed tension the subject began a sustained voluntary isometric contraction. When the tension reached a prescribed interval on the cable tensiometer, the breathing valve on a respirometer was opened so that the subject inhaled and exhaled using the respirometer. The subject discontinued his contraction when he could no longer maintain the prescribed tension, and timing ceased. Results of this study revealed that the 50, 75, and 100 per cent groups increased significantly in strength but not in endurance, except for the 100 per cent group at the 75 per cent contraction. The results indicated that the increased duration of the 50, 75, and 100 per cent groups was due to an increase in strength, not endurance. Although the 25 per cent

group did not gain in strength, it did increase significantly in endurance.[36]

Comparison of Isotonic and Isometric Methods

Which method of contraction, isotonic or isometric, is better in the development of muscular strength is difficult to determine. Darcus and Salter were one of the first investigators to compare the effectiveness of these two training programs. They conducted a study in 1955 to determine the effect of repeated muscular exertion on muscular strength. Muscular strength was determined in pronation and supination of the hand. Two groups of six subjects performed static and dynamic exercises five days per week for twenty-eight sessions. During the training sessions the subjects executed thirty maximum contractions at one minute intervals. Strength was increased by both methods of training.[37]

In 1955 Salter compared the effect of isometric training with the effect of isotonic training when both programs involved exertions in supination of the left hand. The subjects, twelve males and eight females between the ages of 17 and 48, were divided into four

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[36]Doycie Cotten, "Relationship of the Duration of Sustained Voluntary Isometric Contraction to Changes in Endurance and Strength," Research Quarterly, 38:366-74, October, 1967.

[37]H. D. Darcus and Nancy Salter, "The Effect of Repeated Muscular Exertion on Muscle Strength," Journal of Physiology, 129:325-36, August, 1955.

groups. Two of the groups were isometric, with one performing exercises at a rate of two repetitions per minute; the other group, fifteen per minute. The other two groups performed isotonic exercises at rates of either two or fifteen repetitions per minute. The subjects executed 30 contractions daily, four days a week for four weeks. The isometric contractions were gradually increased in force up to the possible maximum over approximately a 4-second period. The isotonic contractions involved lifting a load of about 75 per cent of maximum isometric tension over a 4-second period. To determine muscular strength improvement resulting from training, tests were administered before and after the training period and once a week during the training period. The test consisted of five maximum isometric contractions performed at half-minute intervals and measured by a strain gauge dynamometer. The results of the study indicated that all training procedures produced significant muscular strength improvement, but there were no significant differences among the four methods.[38]

In a study by Baer, *et al.* in 1955, the effects of various methods of muscle training on the production of muscular tension were explored. Sixty-three subjects were divided at random into

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[38]Nancy Salter, "The Effect on Muscle Strength of Maximum Isometric and Isotonic Contractions at Different Repetition Rates," Journal of Physiology, 130:109-13, October, 1955.

six groups, each performing various contractions with different resistances and speeds of contraction. The exercise groups varied in the duration of their programs, but before and after the training periods, the subjects were measured on a strain gauge dynamometer for isometric tension of the wrist flexors. Significant increases in isometric tension were produced from training with isometric exercises performed at a slow rate of ten per minute, although heavy resistive isotonic exercises performed at the same rate of ten per minute produced an increase in isometric tension that was almost as great.[39]

The purpose of a study by Mathews and Kruse in 1957 was to determine the effectiveness of isometric and isotonic contractions of various frequencies. A cable tensiometer was used to measure forearm flexion strength. One hundred and twenty subjects were divided evenly into two groups, each training for four weeks. Both the isotonic and the isometric groups were subdivided into four groups which exercised two, three, four, or five times per week. The isometric groups, using a cable tensiometer, exerted three consecutive 6-second maximal contractions. The isotonic groups exercised until exhaustion on the Kelso-Hellebrandt ergometer. The load for each

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[39]Adrian D. Baer *et al.*, "Effects of Various Exercise Programs on Isometric Tension, Endurance, and Reaction Time in the Human," Archives of Physical Medicine and Rehabilitation, 36:495-502, August, 1955.

subject in the isotonic groups was three-sixteenths of the elbow flexor strength at the time of each test. Results of the study indicated that strength changes depended upon the individual, regardless of exercise frequency or method. However, a greater number of subjects gained significantly in strength from participation in the isometric exercise program. A program of frequent exercise, five days a week, was the most effective in terms of strength gains.[40]

In a study by Rasch and Morehouse in 1957 to determine the effect of static and dynamic exercises on muscular strength and hypertrophy, forty-nine male subjects from the junior class of the College of Osteopathic Physicians and Surgeons were tested. The girth of the upper arm was measured with steel tape, and arm elevation strength and forearm flexion strength were measured by a strain gauge dynamometer. The subjects were divided into two groups: 25 performed isometric exercises, and the other 24 performed isotonic exercises. In each group half of the subjects exercised only the right arm; and the other half, only the left arm. The isotonic training program consisted of progressive resistive exercises practiced three days per week for six weeks. Practiced at two-thirds of maximum isometric strength maintained for fifteen seconds, exercises for the isometric training program were performed three times, three days per week for six weeks. Significant

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[40]Mathews and Kruse, "Effects of Isometric and Isotonic Exercise on Elbow Flexor Muscle Groups," pp. 26-37.

strength gains in forearm flexion and arm elevation in both hands were shown by the isotonic group. Although the isometric group showed no significant strength gain for either arm in forearm flexion, there was a significant strength increase in arm elevation in the exercised arm.[41]

Muller confirmed in 1957 that greater maximal strength is reached with an isometric contraction than an isotonic contraction in the same position during a movement. To measure strength and its increase or decrease by measuring maximal dynamic work is difficult, for maximal dynamic work is as dependent upon a muscle's blood supply as upon muscular strength. Because of these difficulties, results from training experiments with dynamic work have been obscured. However, valid conclusions may be drawn from training experiments with isometric contractions.[42]

A study was conducted in 1959 by Liberson and Asa to determine the effectiveness of daily 6-second isometric exercises with DeLorme's isotonic exercise method. Twenty-three subjects were observed in this study in which the muscles of the hypothenar eminence were exercised isometrically or according to the DeLorme technique. The subjects were divided into an isotonic group, A, and an isometric

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

[42]Muller, "The Regulation of Muscular Strength," pp. 41-47.

group which was divided into two subgroups, B and C. Following the DeLorme technique, Group A exercised the muscles of the hypothenar eminence of the preferred hand four times a week for 12 weeks. The 1 RM and 10 RM were determined weekly. Daily the subjects performed ten exercises with 50 per cent of the 10 RM, ten with 75 per cent of the 10 RM, and ten with 100 per cent of the 10 RM. All movements were performed at a rate of 10 to 15 per minute. Group B performed a single daily 6-second maximal contraction. Group C performed twenty repetitions of 6-second contractions daily. Liberson and Asa found that all subjects showed a significant increase in strength. Group A showed an increase of 103 per cent; Group B, 174 per cent; and Group C, 203 per cent. The isometric groups showed a more rapid increase in strength than the isotonic group.[43]

In 1962 Berger made a comparison of static and dynamic strength increases. Seventy-eight male students participated in the experiment. Static strength was measured by a back-pull machine, and dynamic strength was measured by the back hyperextension lift. The subjects were divided into two exercise groups. Composed of 37 subjects, Group I trained with a back-pull machine. A 6-second maximum isometric contraction was held for three sets with two

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[43]W. T. Liberson and M. Maxim Asa, "Further Studies of Brief Isometric Exercises," Archives of Physical Medicine and Rehabilitation, 40:330-36, August, 1959.

minutes of rest between sets. Using maximum effort, the 41 subjects composing Group II executed eight to twelve consecutive repetitions of the back hyperextension lift. Before and after the twelve week training period the subjects were tested. Results showed that static strength was increased more significantly by static training rather than dynamic training and that dynamic strength was increased more significantly by training dynamically rather than statically.[44]

To determine the effectiveness of a static training program as compared to nine different dynamic training programs in increasing dynamic strength, Berger conducted another study in 1963. Of the 237 male college students participating in this experiment, 57 students trained statically; and 177, dynamically. To measure changes in strength improvement, the dynamic strength test used was the 1 RM in the bench press exercise. Static training involved holding a six to eight second maximum contraction in two positions of the bench press lift: one position with the bar at the chest, and the other position with 90 degree flexion of the forearm. The subjects trained three times weekly for twelve weeks. The nine groups of weight training subjects performed exercise programs which varied from two repetitions with maximum load for one or two bouts to ten repetitions for one, two, or three bouts. To eliminate training

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

differences, the statically trained group performed dynamically one bout of six to ten repetitions with heavy loads in the bench press exercise once a week. Berger found that to increase muscular strength, it was more effective to train statically for six to eight seconds at two different positions than to train dynamically with 2 RM for two bouts, but not as effective as the 6 RM for three bouts. Another conclusion of this study was that to increase strength, static training for six to eight seconds at two different positions was as effective as dynamic training with 2 RM for one or two bouts, 6 RM for one or two bouts, and 10 RM for one, two, or three bouts.[45]

Rasch and Pierson conducted a study in 1963 to determine the effectiveness of isotonic training in developing strength as measured isometrically. The exercises employed were two elbow flexor exercises: two hand curls and two hand reverse curls, and two elbow extensor exercises: two hands military press and supine bench press. The subjects were twenty-seven male college students. Each subject performed three sets of five repetitions of each exercise three days per week for six weeks. Two isometric strength tests were administered. One test measured the strength of the elbow flexors at a 90 degree angle; the other test measured the strength

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[45]Richard A. Berger, "Comparison Between Static Training and Various Dynamic Training Programs," Research Quarterly, 34:121-35, May, 1963.

of elbow extensors. The subjects showed significant gains in the mean isotonic strength but not in the mean isometric strength. Rasch and Pierson concluded that isometric strength does not necessarily improve isotonic movements.[46]

McCraw and Burnham in 1963 conducted an investigation, comparing isometric, isotonic, and speed exercise programs in developing muscular strength. Ninety-three freshmen and sophomore men enrolled in required physical education classes at the University of Texas at Austin were tested then placed randomly in three resistive programs. The subjects trained three times per week for nine weeks. The three resistive programs consisted of: nine isotonic exercises in which the subject lifted and lowered relatively heavy weights at moderate speed; nine isometric exercises performed by contracting the muscle against the resistance of a specially designed strap; and six speed exercises, basically isotonic, which were performed rapidly against a light resistance. To measure arm and leg strength, a cable tensiometer was used. An electric chronoscope measured arm and leg speed and starting speed, and an ergometer measured arm and leg endurance. To measure leg power, a jump and reach test was employed; and the distance the subject could throw a softball was used to measure arm power. McCraw and Burnham found that all three

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[46]Philip J. Rasch and William R. Pierson, "Isotonic Training and Isometric Strength," Perceptual Motor Skills, 16:229-30, 1963.

resistive programs developed strength, although the isometric and isotonic programs seemed to be better for initially stronger persons. The effectiveness of a particular training method, McCraw and Burnham concluded, may depend upon the individual's initial status of strength. In developing maximum muscular strength, speed, endurance, and power, no single training method was found to be adequate. A person having inherent explosive power benefited more from isotonic and speed exercises than isometric contractions.[47]

The effectiveness of isometric and isotonic exercises in the development of muscular strength for individuals having different levels of strength was investigated in a study by Burnham in 1966. Serving as subjects, 148 college men enrolled in required physical education classes at the University of Texas at Austin were tested at the beginning, middle, and end of the training period. The aircraft cable tensiometer measured muscular strength for arm extension and forearm flexion, arm flexion and forearm extension, thigh and leg extension, and trunk flexion. The isometric exercises were performed by exerting three maximum contractions for six seconds; isotonic exercises consisted of performing a series of ten isotonic contractions at 5 RM. The subjects were divided into four groups.

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[47]Lynn W. McCraw and Stanley Burnham, Resistive Exercise in the Development of Muscular Strength and Endurance. Austin: Cooperative Research Project Number 1979, The University of Texas, 1963.

One group used the isometric method for ten weeks; one group used the isotonic method for ten weeks. Another group used the isometric method for five weeks then changed to isotonic exercises for five weeks. The fourth group used the isotonic method for five weeks then changed to isometric exercises for five weeks. All subjects exercised three days per week for ten weeks. Burnham found that for the individual levels of strength or for the group as a whole there were no significant differences between isometric and isotonic contractions in the development of muscular strength.[48]

In 1968 Fischer conducted an investigation to compare the effectiveness of different methods of resistive exercises in the development of muscular strength. Ninety-nine ninth grade boys enrolled in regular physical education classes in the Orange, Texas, Public Schools were divided into three equal groups according to their initial strength test scores and height and weight measurements. Each of the three programs, isotonic, isometric, and power, used exercises to increase strength of the arms and legs. Daily the isotonic group performed three sets of one repetition for each of the prescribed movements. The weight used was the 1 RM. Additional weight was added when the subjects could execute the 1 RM for more

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[48] Stanley Burnham, "A Comparison of Isotonic and Isometric Exercises in the Development of Muscular Strength for Individuals with Different Levels of Strength" (unpublished Doctor's dissertation, University of Texas at Austin, 1966) pp. 11-13, 53-57, 134-8.

than one repetition. The isometric group executed three 6-second maximal contractions against immovable resistance at a predetermined position within the range of movement for the isotonic exercises. The power exercise group performed three sets of one repetition against a resistance allowing a range of movement of 6 to 8 inches. The weight was held for 6 seconds in the contraction position on the third repetition. As strength increased, weight was added to the resistance. All subjects exercised five days a week for nine weeks. At the beginning and end of the training program, isotonic and isometric strength were measured in the muscles involved in arm flexion and extension, forearm flexion, and leg and thigh extension. Isometric strength was measured by the aircraft cable tensiometer, and isotonic strength was determined by the 1 RM. Fischer concluded from the results of this study that all three training programs, except for the muscles used in arm flexion in isotonic contraction, improved strength. A more significant increase in strength was shown by the isotonic and power programs than by the isometric program.[49]

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[49]Harold J. Fischer, "Comparison of Isotonic, Isometric, and Power Training in the Development of Muscular Strength," (unpublished Doctor's dissertation, University of Texas at Austin, 1968) pp. 4-7, 58-62, 111-12.

Effects of Weight Training on Swimming

Limited research has been done on methods of weight training as a means of improving swimming speed. A few studies relative to the effects of weight training on swimming performance have been revealed in the review of literature. In 1955 Davis attempted to determine the effect of a weight training program upon speed in swimming the crawl stroke. He concluded that all 17 subjects increased their swimming speed in the 25-yard and 50-yard swim after nine weeks of weight training.[50]

In 1959 Thompson and Stull conducted a study to determine the effects of various training programs in the speed of swimming. Eighty-one subjects were pretested and posttested in the 30-yard speed swim. The subjects were divided into six training groups and participated in various programs for six weeks. The groups and the number of subjects in each were as follows: (1) The Control Group contained 15 subjects; (2) Weight Training, 15; (3) Swimming Group I, 13; (4) Weight Training and Swimming Group, 13; (5) Swimming Group II, 10; and (6) Swimming Group III, 15. The weight training group used an increased resistance method during their training period. The weight training and swimming group swam three days per week and lifted weights three days per week. They used the same exercises as did the weight training group. Thompson and Stull

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[50]Davis, "The Effect of Weight Training on Speed in Swimming," 28-9.

found that the weight training group did not improve swimming speed, but the swimming and weight training group did improve swimming speed for 30 yards.[51]

In 1960 Nunney conducted a study to determine the relationship between circuit training and the improvement of speed, endurance, weight, and strength of swimmers. The subjects were 24 college men enrolled in required physical education swimming classes. Prior to the beginning of this study, the subjects were instructed for six weeks in the crawl swimming stroke and were in good physical condition. The subjects, equated on the basis of distance swum in a 15-minute endurance test using the front crawl only, were randomly placed in an experimental group or a control group. The six week training program for the experimental group involved six activities in a circuit training program: (1) Two-arm curl, (2) Bounce jumps with knee lift at stall bars, (3) Bent-over rowing motion, (4) leg press, (5) Two-arm press, and (6) Squat thrust. Three laps of the circuit, six activities, were made in fifteen minutes. When completing one lap only, the subject performed each activity at 66 2/3 per cent of the maximum number of repetitions of which he was capable. Every two weeks the amount of weight or number of repetitions was progressively increased. The subjects trained twice a week for six weeks. The

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[51]Stull and Thompson, "Effects of Various Training Programs on Speed of Swimming," pp. 479-85.

experimental group combined circuit training and swimming in the training program, but the control group participated only in swimming. All subjects were tested the week before and the week following the six week training program. The tests were (1) a 15-minute endurance swim, and the recorded score was the number of lengths the subject could swim, (2) a 33 1/3-yard speed swim, and the subjects were measured for height and weight, and (3) strength tests consisting of chins, dips, push-ups, and vertical jump. Nunney concluded that circuit exercises plus swimming increased swimming speed more than did swimming alone.[52]

In 1963 Jensen attempted to determine the effects of five training combinations of swimming and weight training on swimming the front crawl. The five training combinations were as follows: (1) Swimming 5 days, (2) Weight training 5 days, (3) Swimming 3 days and weight training 2 days, (4) Weight training 3 days and swimming 2 days, and (5) Swimming and weight training 5 days. The training combinations were performed five days per week for six weeks. A total of 60 subjects were used with 12 students in each group. Swimming speed tests of 40-yard and 100-yard swims were administered at the beginning of the training programs and at the end of each week. The weight training exercises consisted of isometric, isotonic,

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[52]Nunney, "Relation of Circuit Training to Swimming," pp. 188-98.

and intermediary muscle contractions. Interval swimming for 40-yard and 60-yard distances was used for the swimming training practice. Jensen concluded that all five swimming and weight training combinations resulted in gains in swimming speed for the 40-yard and 100-yard swim. He also concluded that no one combination is superior to the other combinations.[53]

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[53]Jensen, "Effects of Combinations of Swimming and Weight Training on Swimming the Front Crawl," pp. 471-77.

CHAPTER III

PROCEDURES

This study was conducted during the Spring Semester of the 1969-70 school year. The equipment and facilities used were provided by the Department of Athletics and Physical Education for Men at Sam Houston State University in Huntsville, Texas. The 51 subjects for this research consisted of college men enrolled in three intermediate swimming classes of the required physical education program. One class was designated as Group I; another, Group II; and the other, Group III. The entire program was explained in detail to the students the first day of class. Any person not wanting to participate was given an opportunity to change classes or to transfer from one swimming class to another. The subjects' ages ranged from 17 to 24 years; the average age was 19.5 years. The height ranged from 63.5 to 76 inches; the average height was 69.9 inches. The weight ranged from 116 pounds to 260 pounds; the average weight was 160.8 pounds.

Experimental Design

This experiment was designed to determine the effectiveness of two methods of resistive exercises in the development of muscular strength and to determine whether increased muscular strength improves swimming speed. To accomplish this objective, three groups were

used. The three groups with their respective programs were as follows:

Group I -- participated in the exer-genie training program and the swimming training program.

Group II-- participated in the swimming training program only.

Group III--served as a control group, participating in a regular intermediate swimming class.

Each person was encouraged to refrain from participation in other vigorous physical activities during the training periods. Three tests were administered at the beginning and end of the training programs. Two tests were strength tests. One test was an isotonic strength test; the other, an isometric strength test. Both tests measured (1) forearm flexion and (2) forearm extension and arm flexion of each subject. The third test was a swimming speed test; each subject was timed for 30 yards. Subjects were required to use only their arms in this sprint swim. The total number of subjects in each group was as follows: Group I had 18; Group II, 16; and Group III, 17.

Schedule

The subjects participated in the training programs on Monday, Wednesday, and Friday for nine weeks. The duration of each class period was 35 minutes. The exer-genie training program lasted approximately 12 to 15 minutes. The duration of the swimming training program was approximately 20 to 23 minutes. Maximal effort was

stressed in both the tests and the training programs since the subjects' cooperation determined the success of this study.

The first class meeting was Friday, January 30, 1970. This day was used to orientate the students with the investigation. The first week, February 1 through 6, was devoted to discussion, demonstration, and practice by subjects of the testing and training programs. The next two weeks, February 9 through 20, were used to administer the isometric strength test, the isotonic strength test, and the swimming speed test. The subjects began their exercise training programs on Monday, February 23. The training program was executed three times per week for nine weeks. Posttesting was administered on Monday, April 27 through Friday, May 8.

Exer-Genie Training Program

The exer-genie training program included both isometric and isotonic contractions. A description of the isometric and isotonic contractions is as follows:

Isometric Contractions

The subject exerted a maximum contraction for 6 seconds within the isotonic exercise against resistance not allowing movement. The immovable resistance at a specific position was provided by the exer-genie with a person holding the trail rope. Each exercise was performed for three 6-second maximal contractions.

Isotonic Contraction

The subject exerted effort against the exer-genie at a moderate

rate of speed through a complete range of motion except for the 6-second isometric contraction. All exercise movements were performed with a resistance that could be moved only three times through the specified range of motion. The progressive resistive procedure was followed throughout the training period; that is, additional poundage was added to the movement as the muscle gained in strength. Each Friday was designated as test day; and if the subject could perform more than three repetitions of the exercise, additional poundage was added for the next exercise day.

To increase additional poundage on the exer-genie, the calibrated casing was turned so that the bullet pin revolved toward larger hole numbers. The exer-genie contains a single row of numbers, "0-13," above the bullet pin to identify the holes for quick reference. The other rows of numbers are resistance readings (approximate pounds of pull). In order to set the resistance, the bullet pin was depressed and the calibrated casing was moved toward the metal loop. This allowed the casing to turn freely to the desired resistance. When the desired setting was reached, the casing was moved away from the metal loop. This allowed the bullet pin to emerge completely.[54] The exer-genie is shown in Figure 1.

Exercises

The exercises used to achieve the isometric and isotonic contractions are listed and described below:

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[54]Exer-Genie, Inc., Exer-Genie (California, 1964), p. 4.

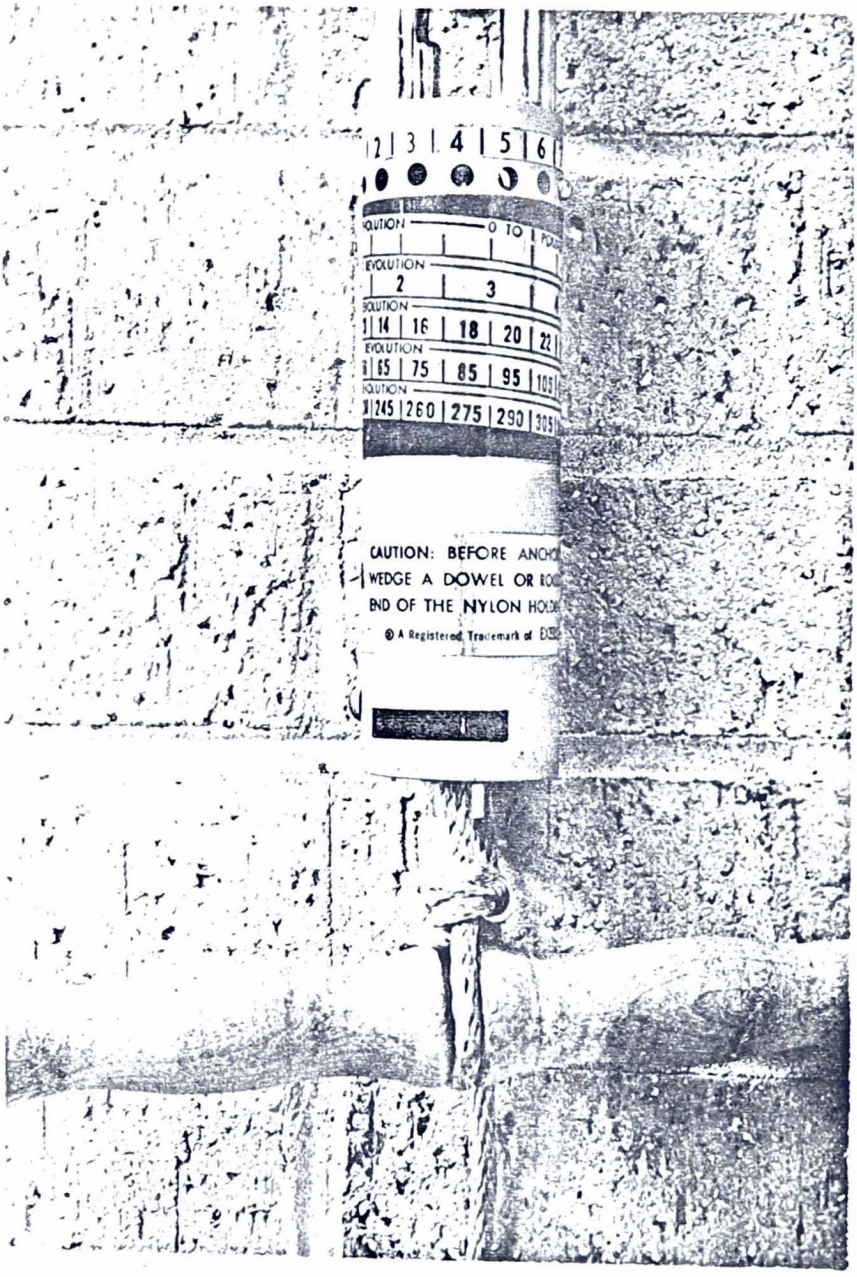

Figure 1

Exer-Genie

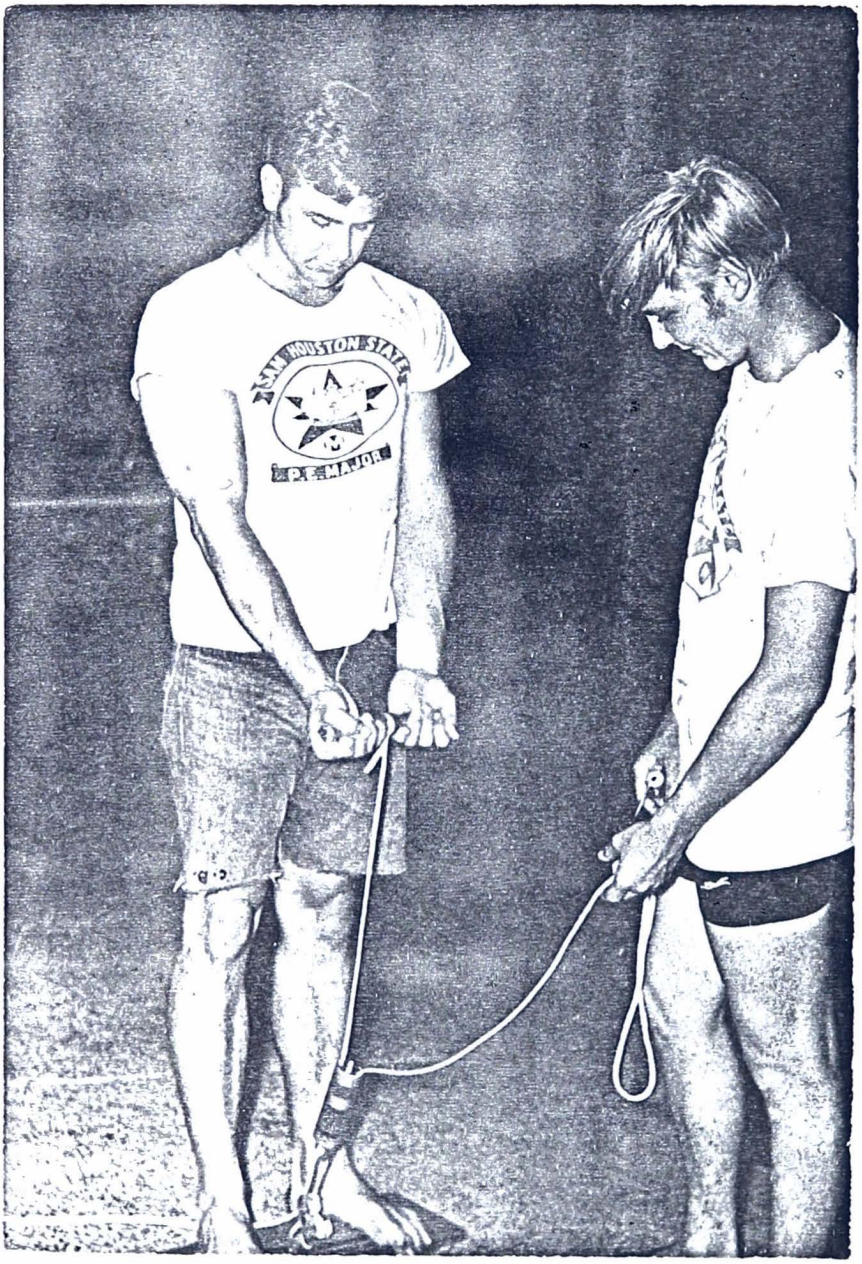

Figure 2

Starting Position for the Curl

Figure 3

6-Second Isometric Hold

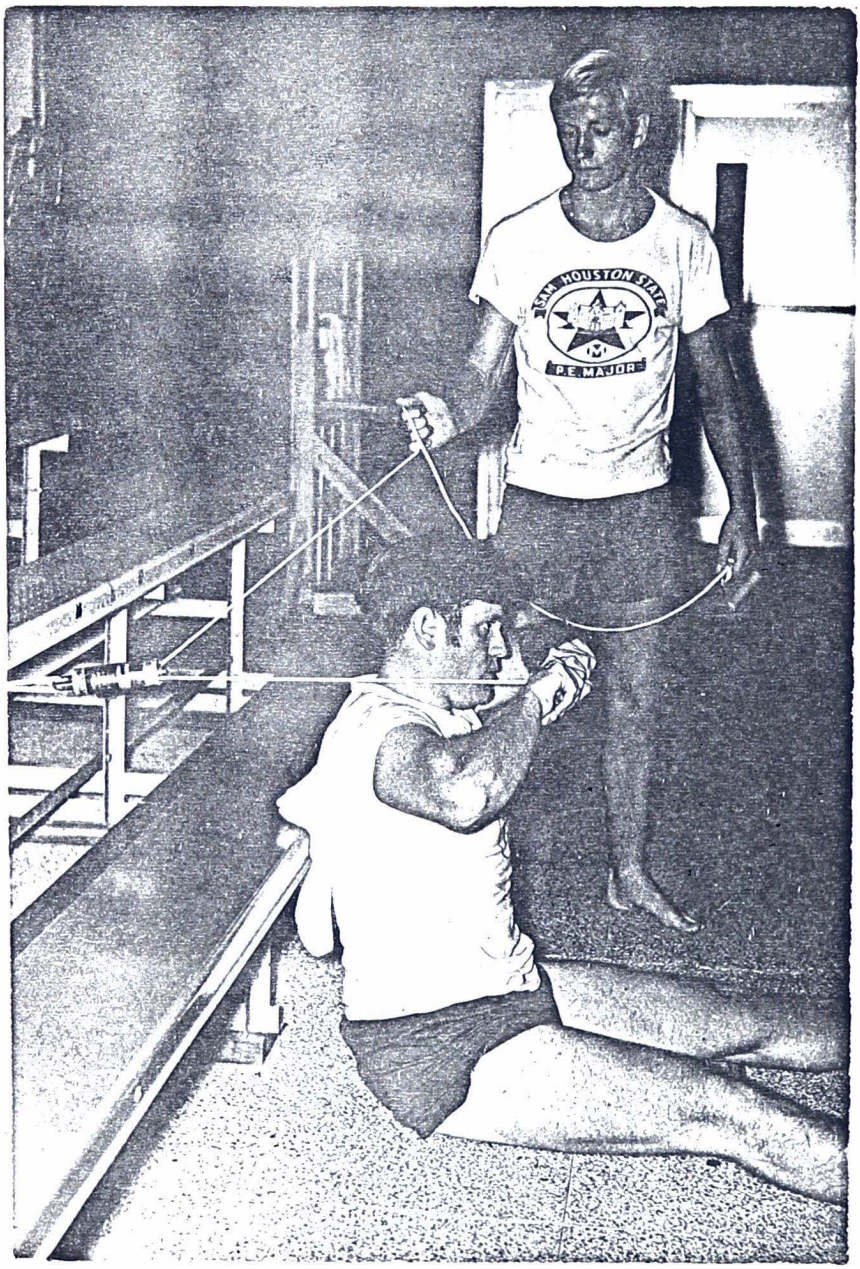

Figure 4

Starting Position for the Bench Press

3. Straight Arm Pull--The subject sat erect with his back against a bench with his arms extended directly overhead. The exer-genie handle was gripped with an overhand grip. The subject started by performing an isometric contraction for 6 seconds as shown in Figure 5. At the end of 6 seconds, the subject's partner released the trail rope. The exercise was continued isotonically against a pre-set resistance. The elbows remained locked throughout the exercise. The subject completed one repetition when his arms came down to shoulder level.

Each exercise was done for one set with a maximal load for three repetitions. There was a 5-second rest period between each repetition. The exercises were done three days per week.

The 18 subjects in the exer-genie training program were paired and assigned to an exer-genie. One subject performed the exercise while his partner manipulated the trail rope. To begin the exercise regimen, the nine subjects performing the exercises executed the first exercise, the curl. These nine subjects assumed a curl position and curled the handle isotonically to approximately a 90 degree angle. The subjects' partners held the trail rope at this position, counted aloud numbers from 1 to 6 with the aid of the second hand on the wall clock, and then released the trail rope. After maintaining this position for 6 seconds isometrically, the subjects continued the curl

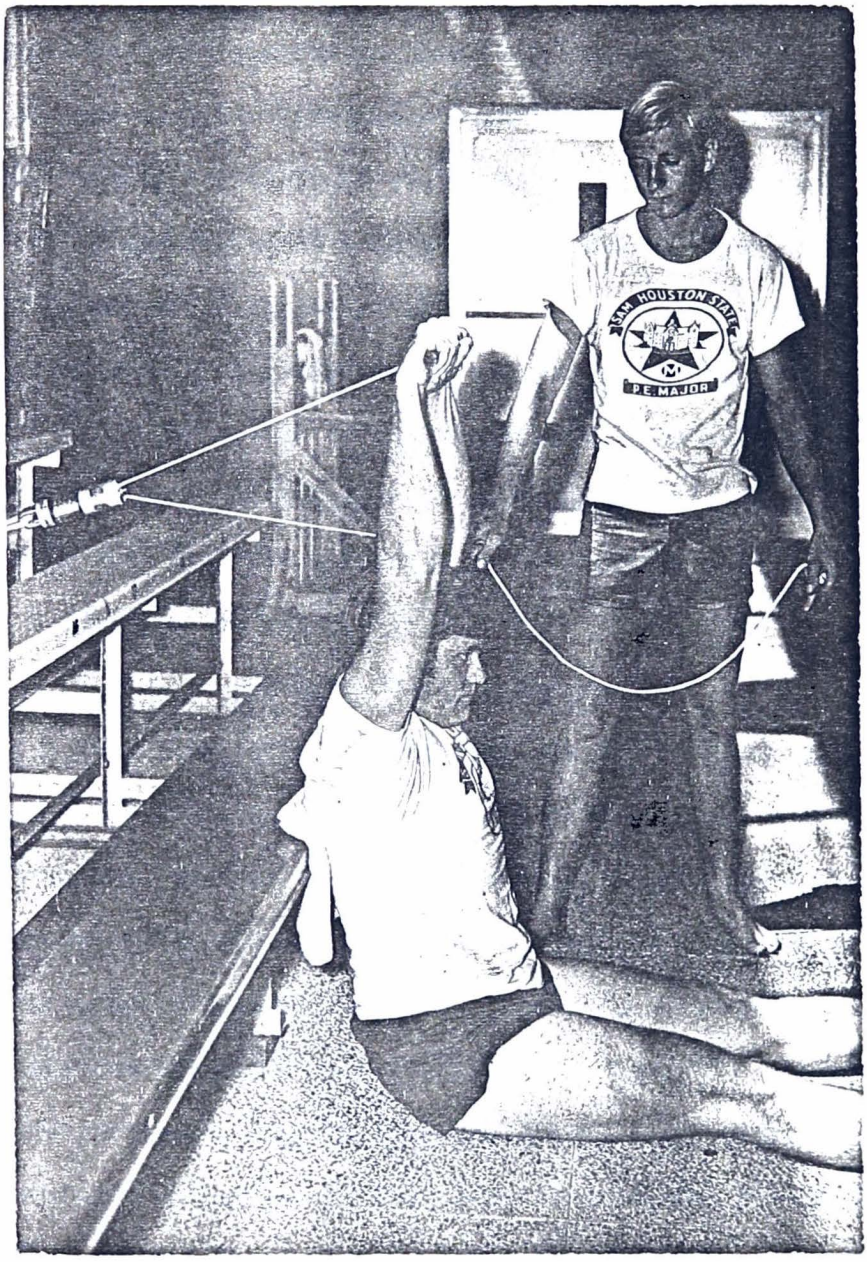

Figure 5

Starting Position for the Straight Arm Pull

isotonically against a pre-set resistance. The subjects completed one repetition when the handle was curled to their chests. At this point the subjects' partners pulled the rope into the original starting curl position for the next repetition and counted from 1 to 5, allowing a rest period between repetitions. Upon the count of five, the subjects began the next repetition and continued this same process until they completed one set of three repetitions. When one set of three repetitions was completed, the subjects changed positions and performed the exercises in the same manner as just explained. The bench press and straight arm pull were executed in the same manner as the curl, except that the isometric hold was performed at the beginning of these two exercises rather than in the middle.

Swimming Training Program

Group I participated in the swimming training program in addition to the exer-genie training program. Group II participated only in the swimming training program. Thompson and Stull tested six groups of subjects to determine whether various training programs affected performance in speed in swimming 30 yards. They reported that all members of the groups who practiced swimming gained in time.[55] A routine was used that is similar to the ones used by Thompson and Stull. The subjects swam the following routine three times a week for nine weeks:

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[55]Stull and Thompson, "Effects of Various Training Programs," p. 485.

1. Eight 25-yard sprints at full speed, using the American crawl only.
2. Arm pull for 100 yards, using no leg kick.

Control Group

Group III was composed of subjects who participated in neither of the vigorous training programs. Group III participated in a regular intermediate swimming class. In this class five basic swimming strokes were taught: American crawl, back crawl stroke, elementary backstroke, breaststroke, and sidestroke. The teaching methods used were those described in Swimming and Water Safety published by the American National Red Cross.[56] The latter minutes of each class period were devoted to diving, playing water basketball, and playing water football.

Testing Procedures

Swimming Speed Test

Each subject was timed for a 30-yard sprint swim. Each subject was timed by an experienced timer with a stop watch. The same timer was used for the pretest and posttest. The subject swam from a starting point to the end of the pool. The subject was in a crawl position and used only his arms on the 30-yard sprint swim. The subject stood in the shallow end of the pool and placed a kick board

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[56] American National Red Cross, Swimming and Water Safety (Washington, D. C., 1968), p. 52.

between his legs at his thighs. He then crossed his legs and locked his feet together, in order to hold the kick board in place during his swim. The kick board was positioned so that all of the exposed area was on the posterior side of the subject. The start was accomplished by pushing off the bottom and coming to a prone glide position. The timer stood directly on the starting line. The subject started at his own discretion; as his head crossed the starting line, the timer started the stop watch as illustrated in Figure 6. As the subject swam, the timer walked on the pool deck ahead of him. When the subject touched the bank on the opposite end of the pool, the timer stopped the watch as shown in Figure 7. Each subject was given two time trials to achieve his maximal effort for the 30-yard sprint swim. The first trial was administered on the first test day; the second trial, on the next class meeting. They performed in consecutive order according to the class roll. The subjects swam in the same order for the second trial as they did for the first trial. Both trials were recorded, and the two were averaged to obtain the test scores. The same procedures were used for pretest and posttest.

Isotonic Strength Test

The isotonic strength testing apparatus was a Universal Gym as seen in Figure 8. The 1 RM was used to measure isotonic strength. The isotonic strength test was administered before the isometric strength test during pretesting and posttesting. Subjects who had lifted weights previously had some idea of how much weight they could

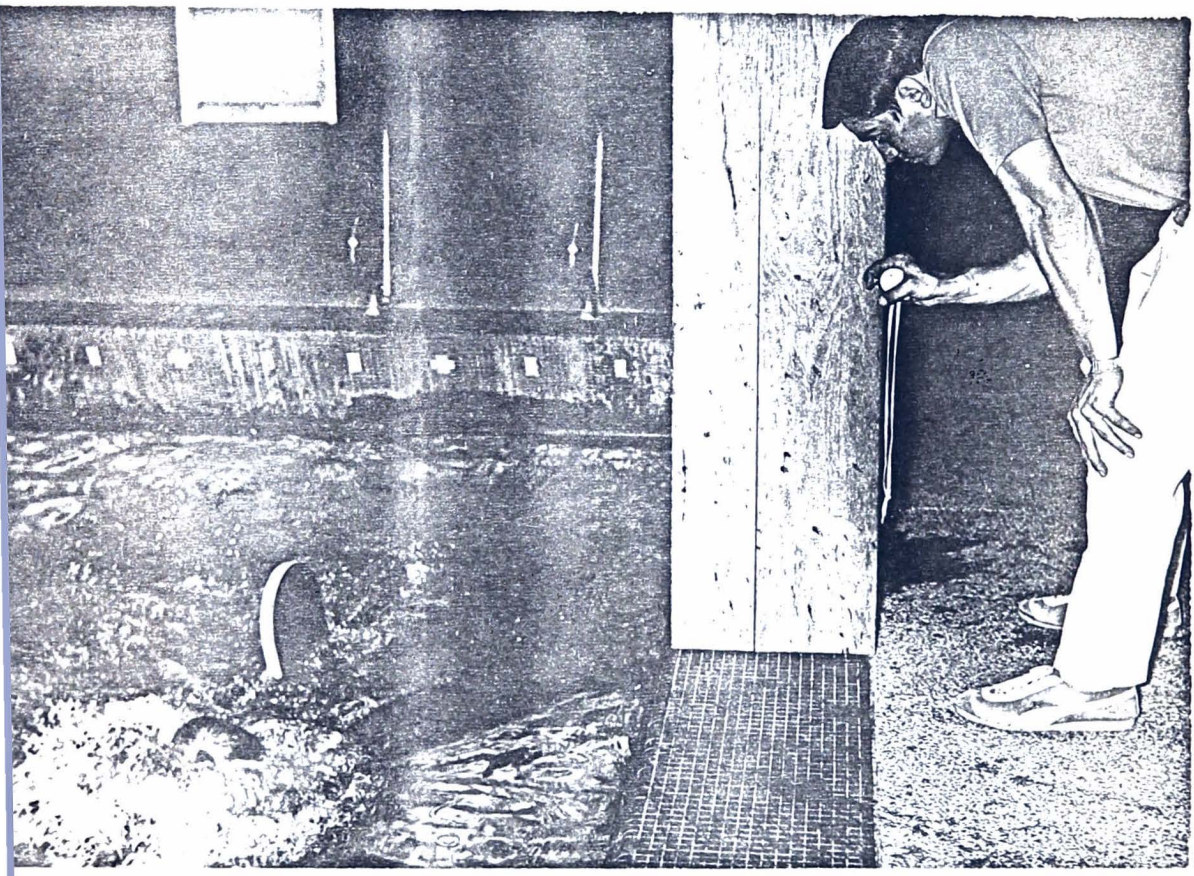

Figure 6

Starting Position for the 30-Yard Speed Swim

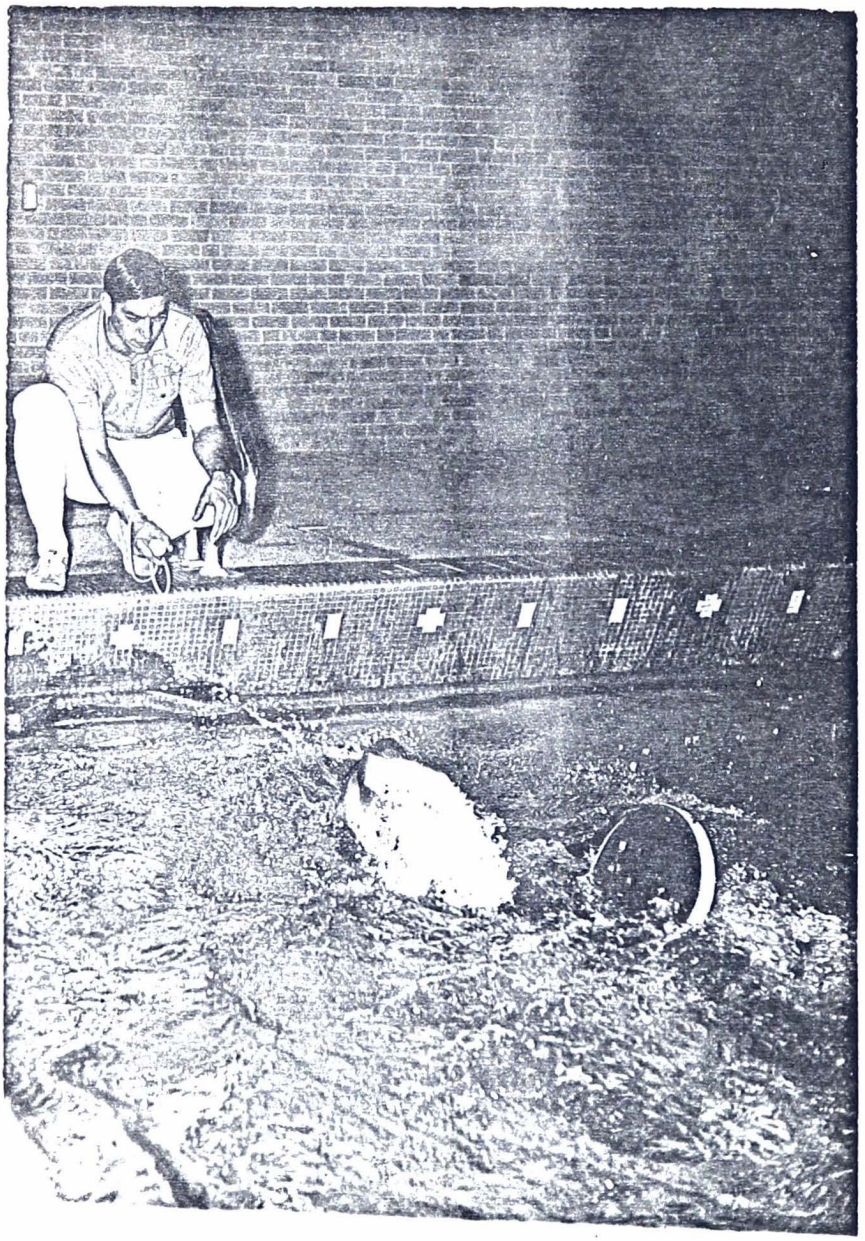

Figure 7

Completion of the 30-Yard Speed Swim

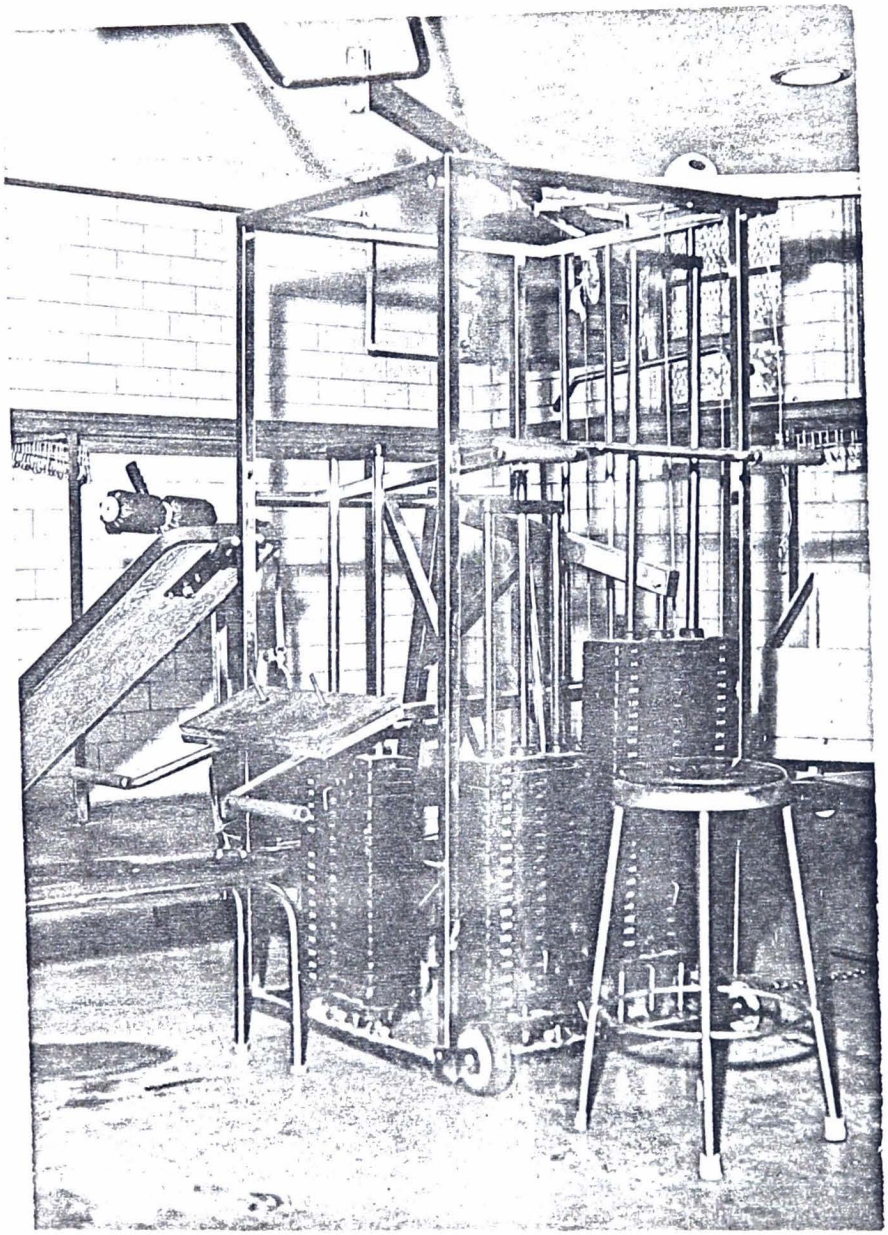

Figure 8

Universal Gym: Isotonic Strength Testing Apparatus

actually lift. Since some students with no previous experience did not know how much weight they could lift, one day was used for all subjects to take practice trials to achieve their approximate 1 RM.

All of the subjects now had a starting weight. Each subject was given one attempt at his approximate 1 RM and then moved to the end of the line. After all of the subjects had attempted their approximate 1 RM, another attempt in the same class roll order was awarded to the subjects if they were unable to lift the prescribed weight on the first attempt. If the subjects were able to lift the prescribed weight on the first attempt, then 10 pounds was added, and the subjects, taking their turns in the class order, attempted to lift this weight. If the subjects were not able to lift their approximate 1 RM on their first and second attempts, then 10 pounds was removed and the subjects attempted to lift this weight. In summary, the subjects received two attempts, when necessary, to attain their 1 RM.

The position of the subjects during the testing procedure is explained below. A tape measure marked off in inches was secured to the handles of both the bench press and the curl weight lifting stations. The purpose for this was to insure the same hand spread on the pretest and the posttest. On the bench press the subject was positioned so that the bar was directly over his chest. His hands were placed on the bar just outside his shoulders. His legs were either extended straight out or dangled toward the floor. He

assumed a starting position as shown in Figure 9 and executed the 1 RM as shown in Figure 10. On the curl the subject stood erect throughout the exercise. His elbows remained close to his body throughout the full range of movement. His knees remained locked. The subject's hands were placed at approximately shoulder width apart. He assumed a starting position as demonstrated in Figure 11 and performed the 1 RM as shown in Figure 12.

Three people were utilized in administering each of the strength tests. One person recorded the amount of weight lifted and the distance of the handspread. Only one score, the 1 RM, was recorded for each exercise in both the pretest and posttest. Another person added or removed weight when necessary. Still another person was utilized to insure proper execution by the subject.

Isometric Strength Test

To measure isometric strength, the aircraft cable tensiometer as shown in Figure 13 was used. Methods employed by Clarke in 1953 were utilized in this investigation.[57] An apparatus as shown in Figure 14 was constructed to test for isometric strength. This apparatus was similar to one constructed by Fischer in 1968.[58] The apparatus contained a bar against which a maximum effort was exerted

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[57]Clarke, "Cable Tension Strength Tests," p. 2.

[58]Fischer, "Comparison of Isotonic, Isometric, and Power Training, p. 72.

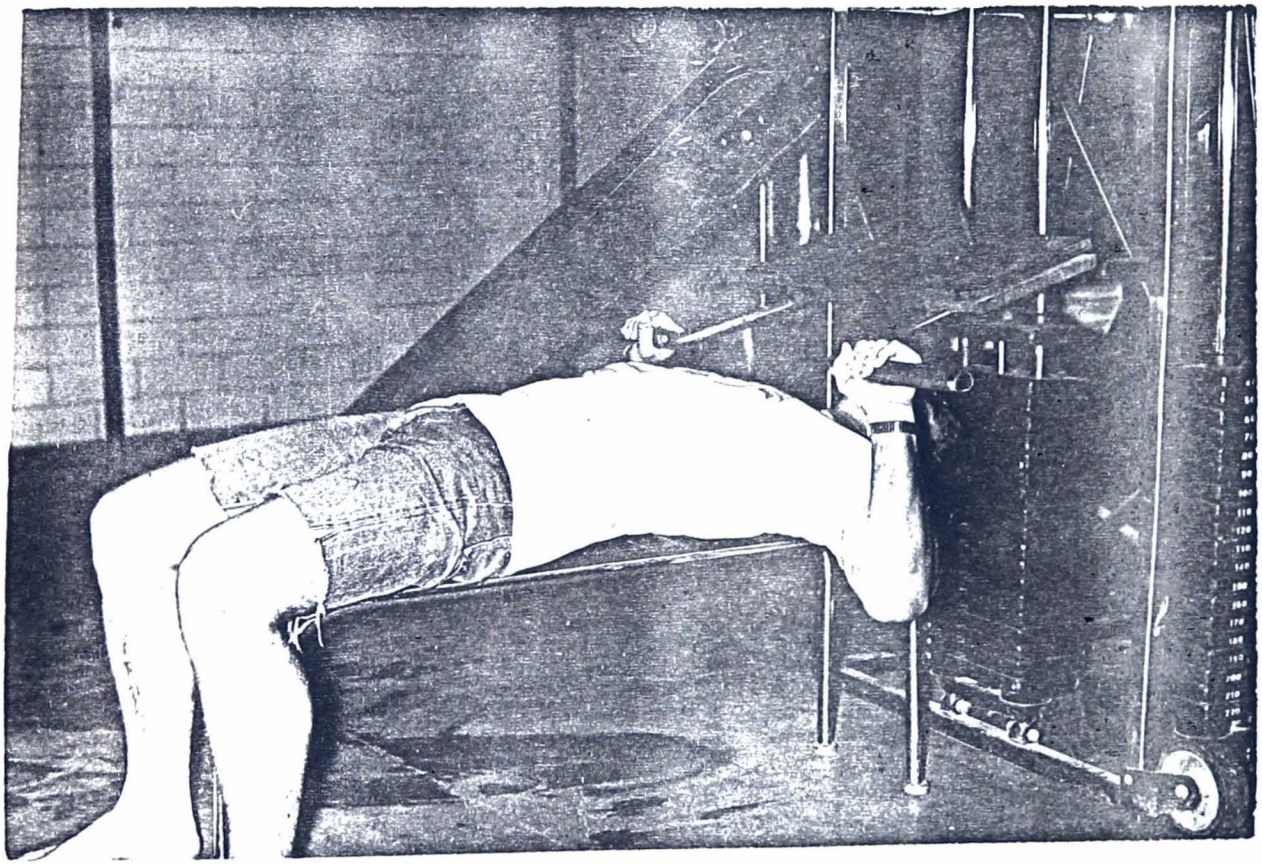

Figure 9

Isotonic Strength Test:

Starting Position for the Bench Press

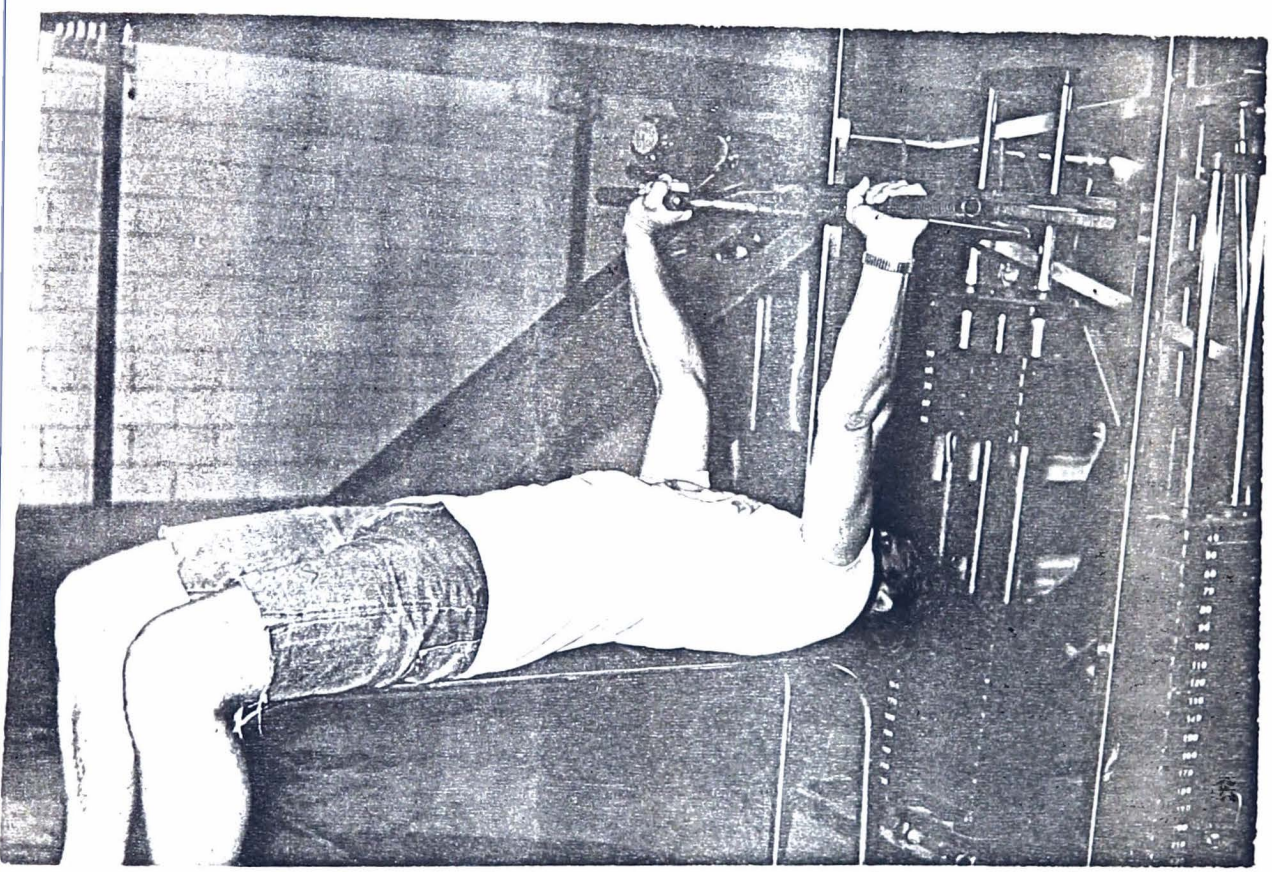

Figure 10

Isotonic Strength Test:

Execution of the 1 RM for the Bench Press

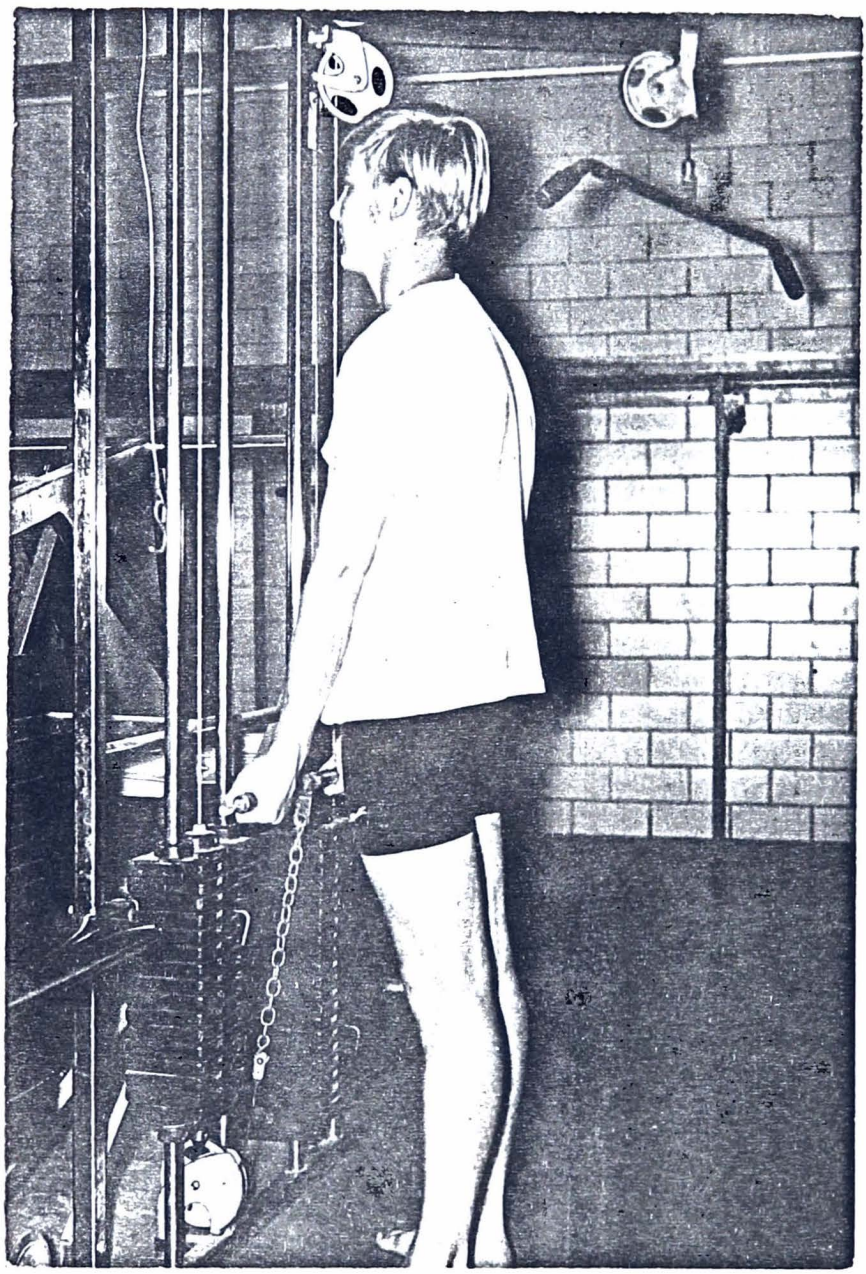

Figure 11

Isotonic Strength Test:

Starting Position for the Curl

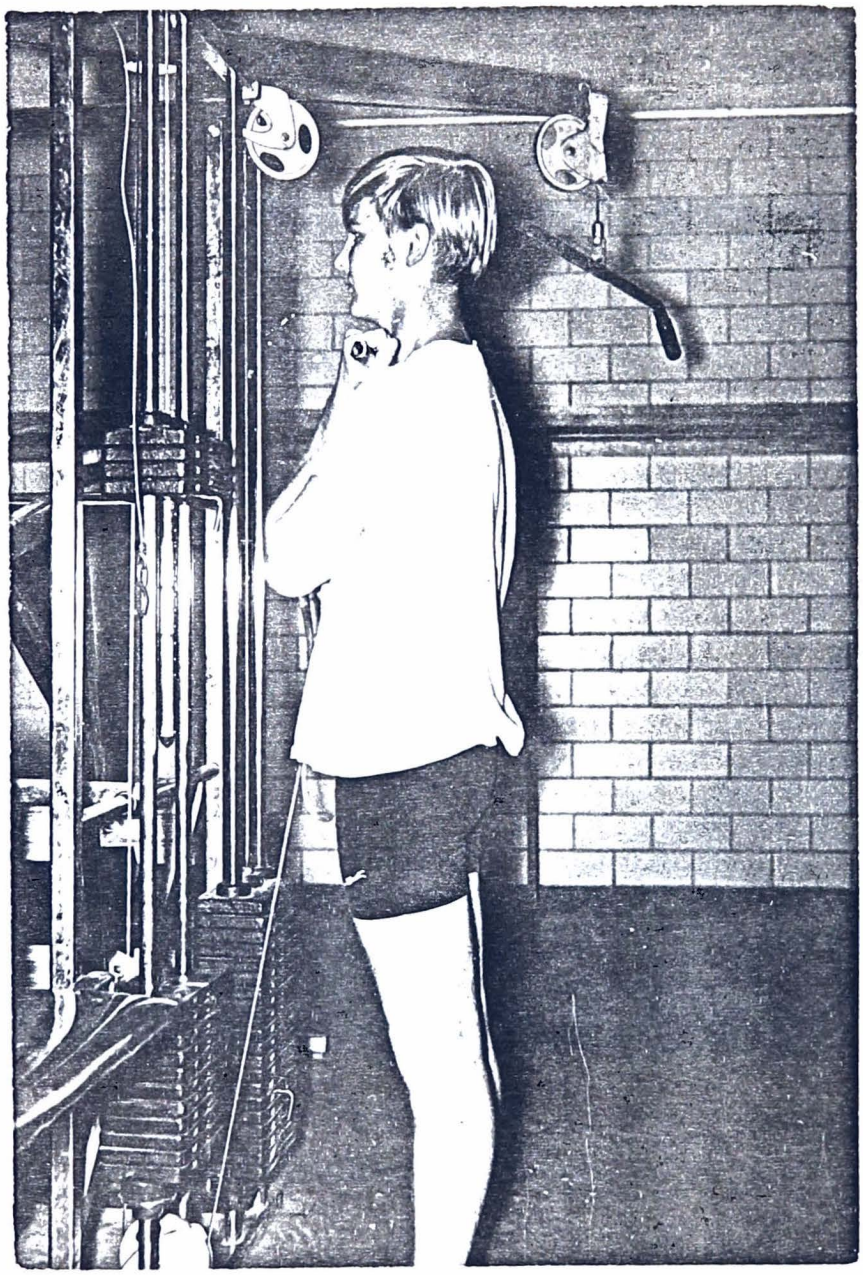

Figure 12

Isotonic Strength Test:

Execution of the 1 RM for the Curl

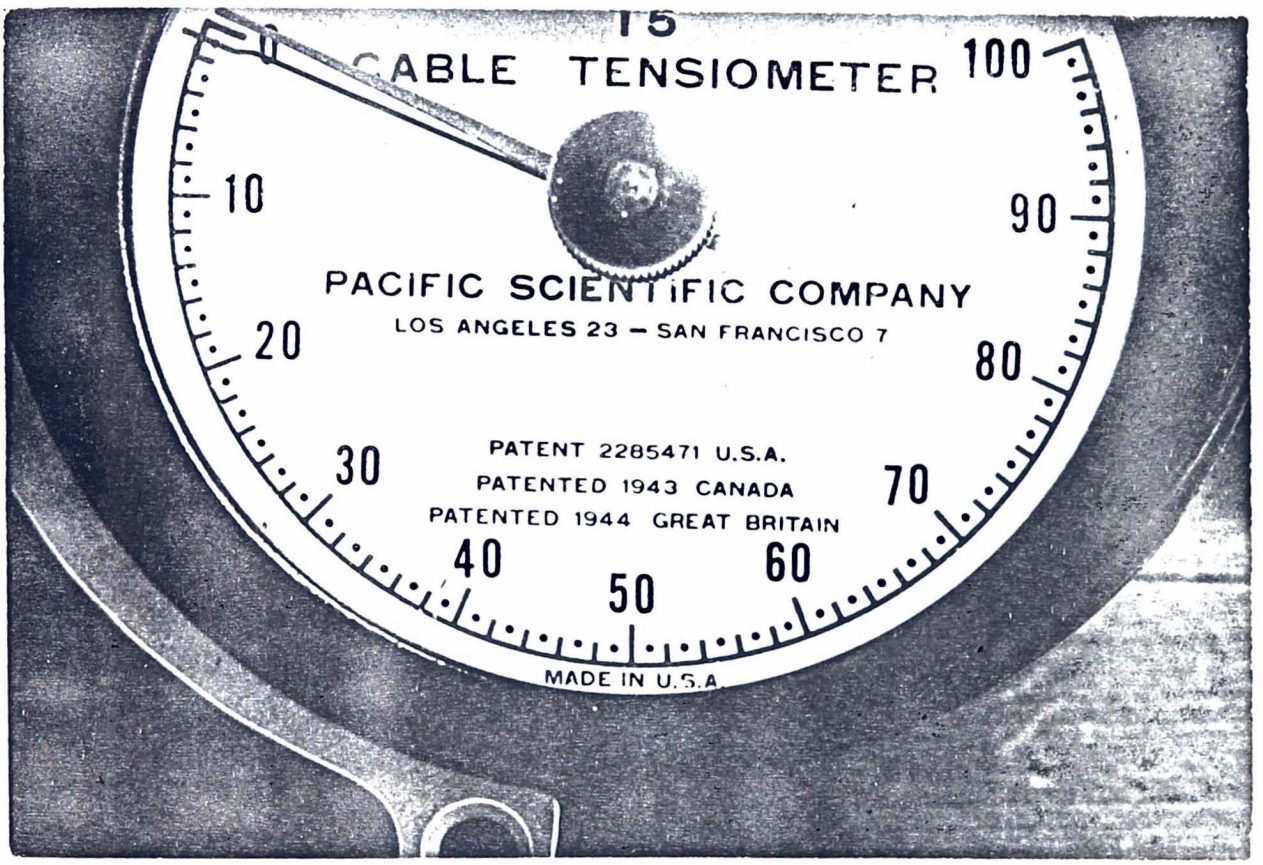

Figure 13

Aircraft Cable Tensiometer

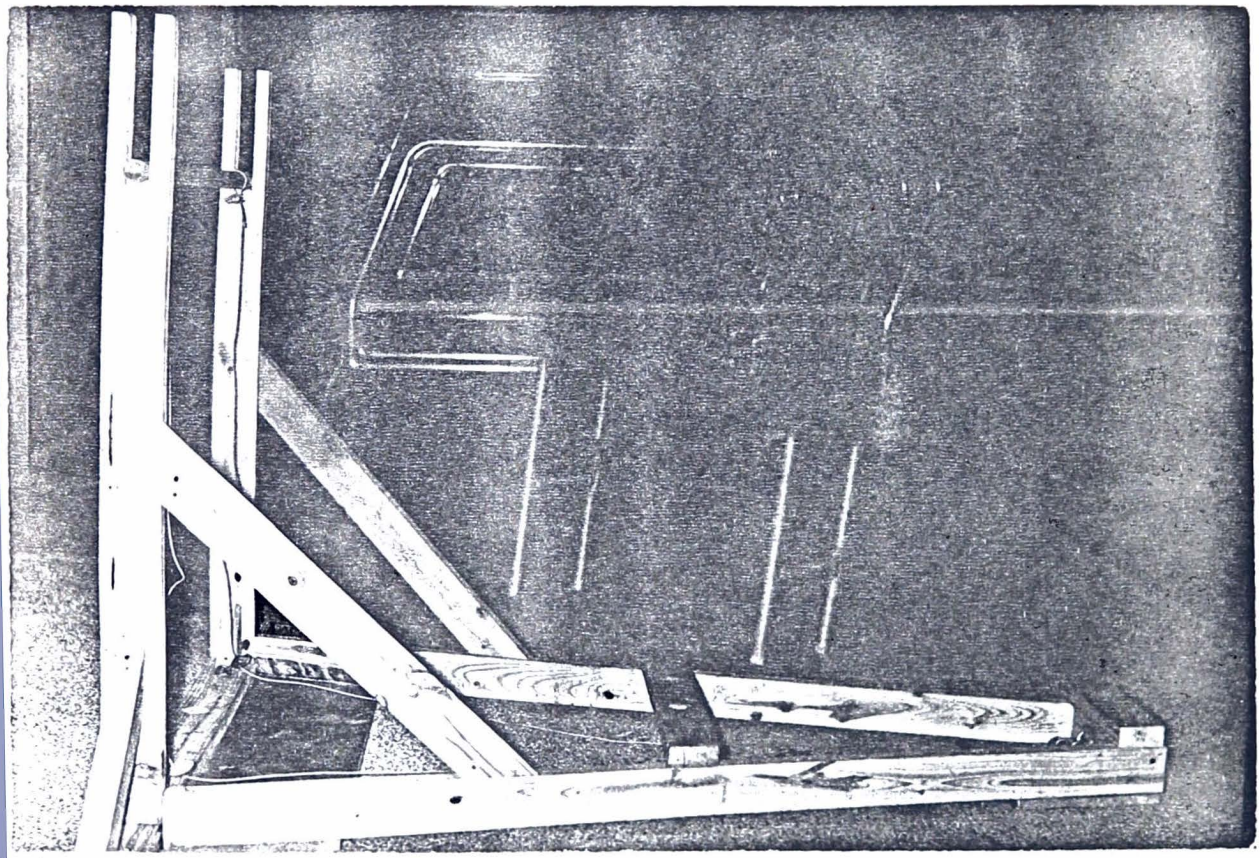

Figure 14

Isometric Strength Testing Apparatus

by the subjects. Two cables running toward the base were attached to the bar. Passing through two pulleys, the cables extended horizontally and junctioned. At this junction a 1/16 inch cable was attached to a hook; the other end of the cable was connected to a chain. The chain could be fastened to the stationary hook at the end of the apparatus as shown in Figure 15. The chain links allowed proper positioning of the bar for the subjects. To measure tension developed in the cable, the tensiometer was placed on the 1/16 inch cable as demonstrated in Figure 16.

On the bench press the subject positioned himself so that the bar was directly over his chest. The chain links were adjusted by measuring the length of the subject's arm and dividing it by two. This measurement produced approximately a 90 degree angle between the forearm and the upper arm of the subject. The subject's hands were placed on the bar just outside his shoulders. His legs were either extended straight out or dangled toward the floor. The isometric strength test for the bench press is shown in Figure 17. On the curl the subject stood erect throughout the exercise. A carpenter's square was used to measure an approximate 90 degree angle between the subject's forearm and upper arm. This 90 degree angle determined the position of the bar which was adjusted by the chain links. The subject's hands were approximately shoulder width apart with his elbows remaining close to the sides of his body during the maximal contraction. The subject was not allowed to bend his knees.

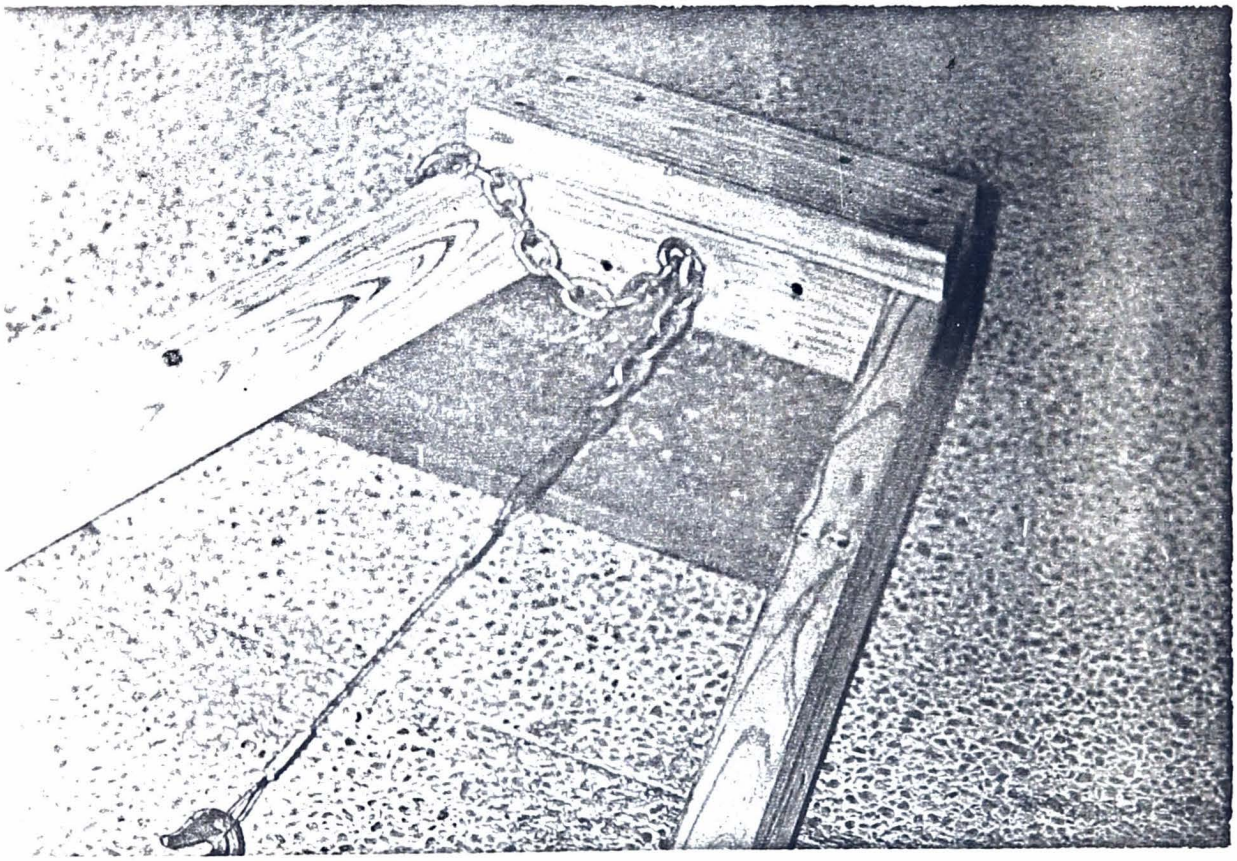

Figure 15

Chain Links for Height Adjustment

Figure 16

Measurement of Isometric Tension

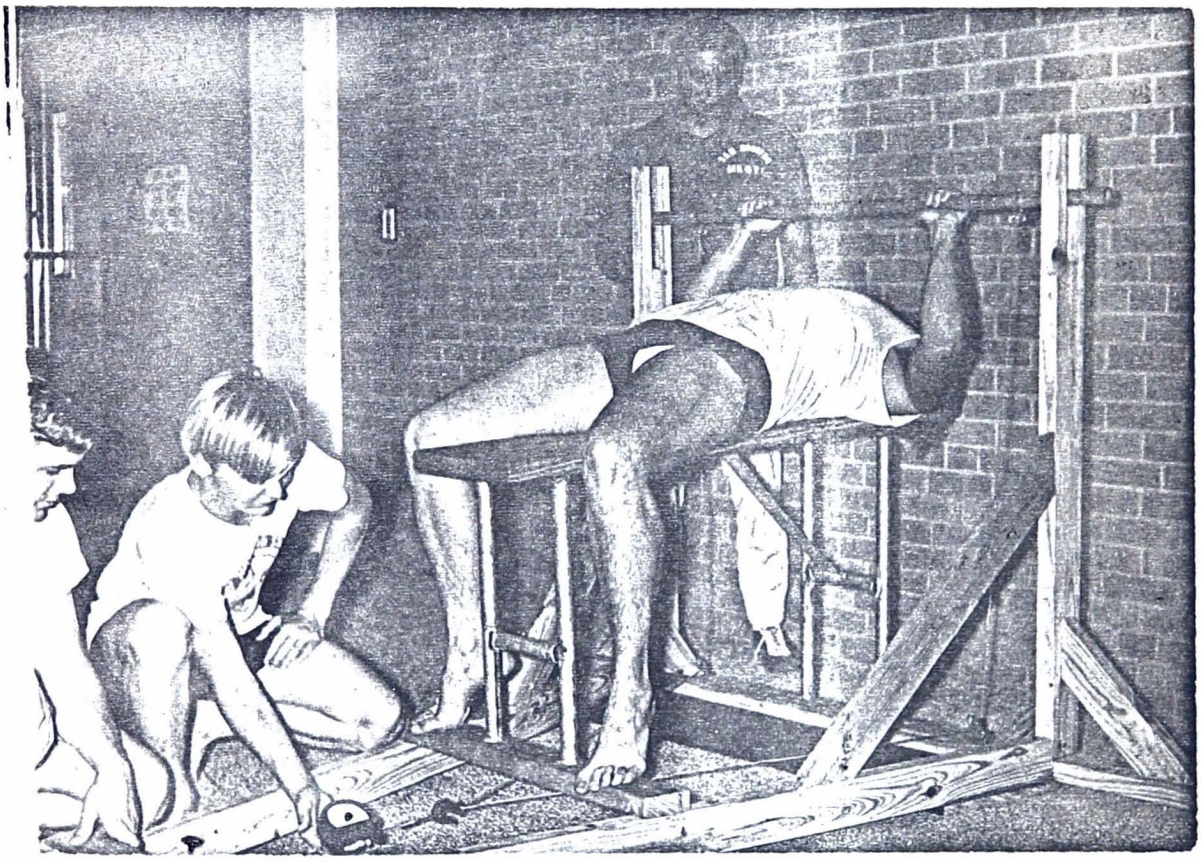

Figure 17

Isometric Strength Test for the Bench Press

The isometric strength test for the curl is shown in Figure 18. A steady even pressure against the bar was stressed on both the bench press and the curl.

One day was utilized as a practice session; each subject was given practice trials to accustom himself to the apparatus. Two days were used for the isometric strength test. One day was used to obtain measurements for the curl; the other, measurements for the bench press. The subjects performed their maximal efforts in consecutive order according to the class roll. Each subject was allowed two trials to achieve his maximal effort. Each subject performed the first trial and then moved to the end of the line. When all the members of the class completed their first trials, the second trial was administered in the same manner. Both trials were recorded, and the two trials were averaged to obtain the test scores. The assistance of three people was required to administer the test. One person recorded the amount of tension developed and the number of chain links needed by each of the students. Another person handled the tensiometer and determined the scores. The other person insured the proper execution by the subjects.

The procedures for the isotonic strength test and the isometric strength test were done in the same manner for both the pretest and the posttest. Both the isotonic and isometric strength tests measured (1) forearm flexion and (2) arm flexion and forearm extension.

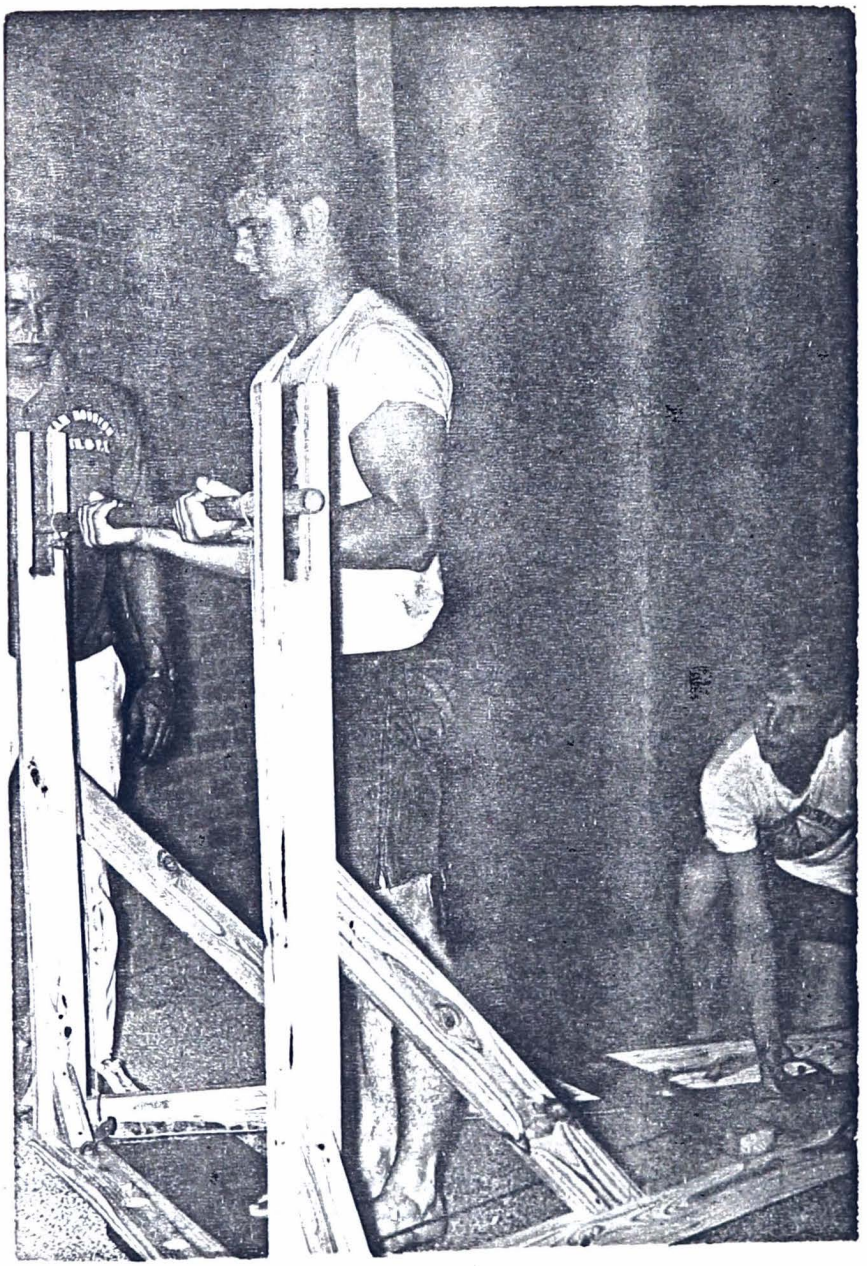

Figure 18

Isometric Strength Test for the Curl

CHAPTER IV

ANALYSIS AND DISCUSSION

Methods of Analysis

The purpose of this investigation is to determine the effectiveness of two methods of resistive exercises in the development of muscular strength and to determine whether increased muscular strength improves swimming speed. The comparison of group average pretest and group average posttest scores of the swimming speed test, the isotonic strength test, and the isometric strength test provides the statistical data that will be analyzed. The pairing design t-test was used to determine significant differences between group average pretest scores and group average posttest scores of each group with n-1 degrees of freedom where n is the number of students in a group.[59] Scores that were significant in the pairing design t-test were examined by the Newman-Keuls multiple-range test. This test provides a sequential method of examining all differences between pairs of group means.[60]

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[59] Charles M. Woolf, "Pairing Design Test," Principles of Biometry (Princeton, New Jersey: D. Van Nostrand Company, Inc., 1968), pp. 70-77.

[60] Woolf, "Introduction to Analysis of Variance," *ibid.*, pp. 101-109.

The method of calculation for the pairing design t-test is as follows:

$$t \text{ ratio} = \frac{\bar{X}d}{s_{\bar{X}_d}}$$

where $\bar{X}d$ is the mean difference (the mean difference is derived by subtracting the average pretest scores from the average posttest scores in a given group), and where $s_{\bar{X}_d}$ is the standard error of the mean difference. The value of $s_{\bar{X}_d}$ is:

$$s_{\bar{X}_d} = \frac{sd}{\sqrt{n}}$$

where s_d is the standard deviation of differences between posttest and pretest scores and n equals the number of students in a group.

The formula for the standard deviation is:

$$s_d = \frac{\sqrt{\Sigma\ (d-\bar{X}_d)^2}}{n-1}$$

where d is the difference between posttest and pretest scores for a student. This is the variable of analysis.

The Newman-Keuls test is designed to test all possible pairs of average score differences among the three groups. In order to test the null hypothesis of equal average differences, the appropriate test statistic is the Studentized range:

$$q = \frac{w}{s_{\bar{X}_d}}$$

where w is the largest mean difference minus the smallest mean difference,

and where $s_{\bar{X}_d}$ is the combined or pooled standard error of the average score differences.

Results

To accomplish the purpose of this investigation, three groups were used. The three groups with their respective programs are as follows:

Group I -- participated in the exer-genie training program and swimming training program.

Group II-- participated in the swimming training program only.

Group III--served as a control group, participating in a regular intermediate swimming class.

Three tests were administered at the beginning and end of the training programs. One test was a swimming speed test in which each subject was timed for 30 yards. The subjects were required to use only their arms in this sprint swim. The other two tests were strength tests. One test was an isometric strength test; the other, an isotonic strength test. Both tests measured (1) forearm flexion and (2) forearm extension and arm flexion of each subject. The exercises used to obtain these measurements were the curl and the bench press, respectively. The total number of students in Group I was 18; Group II, 16; and Group III, 17.

In the swimming speed test the subjects were allowed two trials to achieve their best times for 30 yards on both the pretest and the posttest. The group averages in seconds for all three groups for each

of the two trials in the pretest and posttest are shown in Table I on page 84. In the isometric strength test a pretest and a posttest were administered for the curl and the bench press. The subjects were given two trials to achieve their maximal efforts for the curl and the bench press in both the pretest and posttest. A group average for each of the trials for the curl and bench press in the pretest and posttest is shown in pounds for all three groups in Table I on page 84.

The group averages of the two trials in the pretest and the group averages of the two trials in the posttest for the swimming speed test and the isometric strength test are shown for all three groups in Table II on page 85. In the isotonic strength test the subject was given two attempts at certain weights until he achieved his 1 RM. Only one score, the 1 RM, was recorded for the pretest and the posttest. The group average pretest scores and the group average posttest scores for the bench press and curl in the isotonic strength test are also shown in Table II on page 85.

The pairing design t-test was used to examine differences between pretest and posttest scores for all three groups. Since each student was given a pretest and a posttest, the differences in the scores were the variables of analysis. The group average differences between the posttest scores and the pretest scores and the standard errors of these group average differences for the five tests given to the three groups of students are listed in Table III on page 86. The null hypothesis for Table III in all 15 cases was that the differences

TABLE I

GROUP AVERAGE SCORES FOR EACH OF THE TWO TRIALS IN PRETEST AND POSTTEST FOR SWIMMING SPEED TEST AND ISOMETRIC STRENGTH TEST FOR ALL THREE GROUPS

	Swimming Speed Test measured in seconds				Isometric Strength Test measured in pounds: Curl which measured forearm flexion				Isometric Strength Test measured in pounds: Bench Press which measured forearm extension and arm flexion			
	Pretest		Posttest		Pretest		Posttest		Pretest		Posttest	
Groups	1st trial	2nd trial	1st trial	2nd trial	1st trial	2nd trial	1st trial	2nd trial	1st trial	2nd trial	1st trial	2nd trial
I-participated in the exergenie training program and swimming training program	24.34	24.79	23.78	22.94	68.72	64.11	67.17	72.50	107.50	103.94	115.44	115.61
II-participated in the swimming training program only	22.95	22.54	22.30	23.44	68.06	64.13	65.69	64.88	105.06	102.06	112.81	111.06
III-served as the control group, participated in a regular intermediate swimming class	25.86	25.26	25.45	25.24	66.18	69.47	67.88	68.06	108.88	107.47	107.35	105.06

TABLE II

GROUP AVERAGE SCORES OF THE TWO TRIALS IN PRETEST AND POSTTEST FOR SWIMMING SPEED TEST, ISOMETRIC STRENGTH TEST, AND ISOTONIC STRENGTH TEST FOR ALL THREE GROUPS

			Isometric Strength Test measured in pounds				Isotonic Strength Test measured in pounds			
	Swimming Speed Test measured in seconds		Curl which measured forearm flexion		Bench Press which measured forearm extension and arm flexion		Bench Press which measured forearm extension and arm flexion		Curl which measured forearm flexion	
Groups	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
I-participated in the exer-genie training program and the swimming training program	24.57	23.36	66.42	69.83	105.72	115.53	153.89	162.78	76.67	91.67
II-participated in the swimming training program only	22.75	22.87	66.09	65.28	103.56	111.94	153.75	161.88	73.13	83.13
III-served as the control group, participated in a regular intermediate swimming class	25.56	25.35	67.82	67.97	108.18	106.21	154.71	160.59	67.06	78.24

TABLE III

GROUP AVERAGE DIFFERENCES AND THEIR STANDARD ERRORS BETWEEN POSTTEST AND PRETEST SCORES FOR SWIMMING SPEED TEST, ISOMETRIC STRENGTH TEST, AND ISOTONIC STRENGTH TEST FOR ALL THREE GROUPS

		Isometric Strength Test measured in pounds		Isotonic Strength Test measured in pounds	
Groups	Swimming Speed Test measured in seconds	Curl which measured forearm flexion	Bench Press which measured forearm extension and arm flexion	Bench Press which measured forearm extension and arm flexion	Curl which measured forearm flexion
I-participated in the exer-genie and swimming training program	-1.21* .52	3.42* 1.47	9.81* 3.57	8.89** 2.79	15.00** 3.99
II-participated in the swimming training program only	.12 .41	- .81 1.27	8.38* 3.13	8.13** 2.65	10.00** 3.15
III-served as the control group, participated in a regular intermediate swimming class	- .21 .41	.15 1.01	-1.97 3.17	5.88** 2.56	11.18** 3.14
Results of the Newman-Keuls test	No test needed	No test needed	No difference between strength gains in Groups I and II	No difference in the three strength gains	No difference in the three strength gains
Results of the pairing design t-test	*Significantly different from zero at the 5 per cent probability level. **Significantly different from zero at the 1 per cent probability level.				

between the group average pretest and group average posttest scores were zero. A t-table was used to determine the probability percentages of t-values.[61] If a calculated t-ratio was greater than a critical value obtained from the t-table, then the null hypothesis of no significant gain from pretest to posttest was rejected. The alternative hypothesis of a statistically significant difference between the group average pretest and posttest scores was then accepted. The critical t-values for the five per cent and one per cent probability levels are presented below for each group:

Group I	t.05, 17 d.f. = 2.11
	t.01, 17 d.f. = 2.90
Group II	t.05, 15 d.f. = 2.13
	t.01, 15 d.f. = 2.95
Group III	t.05, 16 d.f. = 2.12
	t.01, 16 d.f. = 2.92

The results of the pairing design t-test are noted by single and double asterisks in Table III on page 86. All group average differences between pretest and posttest scores marked by asterisks are significantly different from zero, i.e., there was a significant difference between group average posttest and pretest scores. The five per cent probability level signifies that there is a five per cent chance that a difference as large or larger than the observed difference will occur due to chance, i.e., when the null

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[61] Woolf, *ibid.*, p. 329.

hypothesis is really true. The one per cent probability level assures a more valid difference.

The Newman-Keuls multiple-range test provides further validation of the results of the pairing design t-test. Group average differences that were significant in the pairing design t-test were also examined by the Newman-Keuls test, which provides a sequential method of comparing all differences between pairs of group means. The null hypothesis for Table III in three of the five cases was that there was no difference between pairs of group mean differences. The three cases were the isotonic strength test for the bench press and the curl, which measured (1) forearm extension and arm flexion and (2) forearm flexion, respectively; and the isometric strength test for the bench press, which measured forearm extension and arm flexion. A q-table was used to determine the probability percentages of q-values.[62] If a calculated q-ratio was smaller than a critical value obtained from the q-table, then the null hypothesis of no difference between pairs of group mean differences was accepted. The critical values of q at the .05 probability level are 3.43 when comparing the largest and the smallest of the three group means and 2.85 when only two group means are compared. The results of the Newman-Keuls test are noted in Table III on page 86.

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[62] Woolf, *ibid.*, p. 332.

The significant results of the pairing design t-test and the Newman-Keuls multiple-range test noted in Table III are listed below:

1. Students in Group I, who participated in the exer-genie training program and swimming training program, gained significantly in speed of swimming for 30 yards. The group average gain in swimming speed from pretest to posttest was 1.21 seconds. Those students in Group II who participated in the swimming training program only and Group III, the control group, did not gain in swimming speed. In conclusion, the students who participated in a combination of the exer-genie training program and the swimming training program significantly improved their swimming speed, whereas Groups II and III did not gain in swimming speed.

2. The students in Group I, who participated in the exer-genie training program and the swimming training program, gained significantly in isometric strength for the curl, which measured forearm flexion. The group average gain in isometric strength for the curl was 3.42 pounds. Those students in Group II, who participated in the swimming training program only, and Group III, the control group, did not gain in isometric strength.

Groups I and II gained significantly in isometric strength for the bench press which measured forearm extension and arm flexion. The group average gains in isometric strength for the bench press in Groups I and II were 9.81 and 8.38 pounds, respectively. Groups I and II gained significantly only at the five per cent level of

confidence. The Newman-Keuls test showed that there was no difference in the amount of gains for the bench press in Groups I and II. Those students in Group III did not gain in isometric strength for the bench press. In conclusion, the combination of the exer-genie training program and the swimming training program did not increase isometric strength for the bench press more than did the swimming training program alone.

3. All three groups of students gained significantly in isotonic strength for both the bench press and the curl, which measured (1) forearm extension and arm flexion and (2) forearm flexion, respectively. The group average gains for the bench press from pretest to posttest for Groups I, II, and III were 8.89, 8.13, and 5.88 pounds, respectively. The pairing design t-test showed that Groups I and II gained significantly at the one per cent level of confidence, whereas Group III gained significantly at the five per cent level of confidence. The average gains for the curl from pretest to posttest for Groups I, II, and III were 15.00, 10.00, and 11.18 pounds, respectively. These three gains were significantly different from zero at the one per cent level of confidence. The Newman-Keuls test showed that there was no difference in the amount of gains in all three groups for both the bench press and the curl. In the isotonic strength test for the bench press and the curl, the gains in strength for Group I were higher, but not statistically higher, than the gains of the other two groups.

Discussion

The results of this investigation partially support the opinion of many physical educators and coaches that the success of physical performance is determined to a large extent by increased muscular strength. The only case in which the students of Group I, who participated in the exer-genie training program and the swimming training program, gained significantly in strength over the other two groups was in the isometric strength test for the curl. However, the trend in Table III on page 86 is that Group I had higher gains of strength both isotonically and isometrically than did the other two groups. Students who participated in a combination of the exer-genie training program and the swimming training program improved their swimming speed significantly, whereas those students in the swimming training program only (Group II) and the control group (Group III) did not improve their swimming speed. However, it is not apparent which training program, exer-genie or swimming, contributed to this increase in swimming speed. There is evidence that the increase in swimming speed is due to the exer-genie training program because students in Group II, who participated in the swimming training program only, did not increase their swimming speed.

All three groups of students gained significantly in isotonic strength for both the bench press and the curl. The students in Group I, who participated in the exer-genie training program and the swimming training program, had higher strength gains in both the bench

press and the curl than the other two groups, but these gains were not statistically higher.

Group I also had higher gains in isometric strength for both the curl and the bench press. Group I gained significantly in the curl, while Groups II and III did not gain in isometric strength. Although Group I had a higher gain in isometric strength for the bench press than Group II, the gain was not statistically higher.

Since the same muscles were tested in the isotonic and isometric strength tests, a comparison of isotonic and isometric methods can be made. All three groups showed greater strength gains isotonically than isometrically for the curl. With the exception of the control group, isotonic strength gains for the bench press were approximately equivalent to isometric strength gains for the bench press.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

Purpose

The purpose of this investigation was to determine the effectiveness of two methods of resistive exercises in the development of muscular strength and to determine whether increased muscular strength improved swimming speed. To achieve the purpose of this investigation, two experimental groups and a control group were used. One experimental group participated in an exer-genie training program and a swimming training program. The other experimental group participated in the swimming training program only. The exer-genie combined both methods of resistive exercises. The two methods of resistive exercises were:

1. Isometric method in which a maximum contraction was exerted for 6 seconds within the isotonic exercise against a resistance that did not allow movement.

2. Isotonic method in which a pre-set resistance was moved through a complete range of motion except for the 6 second isometric contraction.

Literature

A review was made of literature relating to isotonic and isometric

training methods of exercise and the effect of weight training on swimming speed. Beginning with the classic studies of DeLorme, the investigator reviewed fifteen studies on isotonic exercise programs. Eleven experiments on isometric exercise programs were reviewed. A review of thirteen studies comparing these two programs was made. Limited research has been done on methods of weight training as a means of improving swimming speed. Because of this lack of evidence, the investigator could review only four studies pertinent to the value of this program.

A summary of the results of studies on muscular strength development is as follows:

1. Muscular strength is developed by exercises employing heavy resistance and low repetition.

2. Regardless of how much a muscle is used, it will not grow in size or strength until it is overloaded.

3. Increased work intensity results in muscle hypertrophy; the greater the overload, the greater the amount of hypertrophy.

4. In the development of muscular strength there is a deviation in the optimum number of repetitions for both isometric and isotonic exercise programs.

5. Although both isometric and isotonic exercise methods develop strength, there is no significant difference between the two methods.

The results of studies on the effect of weight training upon swimming speed are summarized below:

1. Swimming speed in the 25-yard and 50-yard swim is increased after 9 weeks of weight training.

2. Weight training alone does not improve swimming speed, whereas swimming and weight training improve swimming speed for 30 yards.

3. Circuit exercises plus swimming increase swimming speed more than does swimming alone.

4. No one combination of weight lifting and swimming programs is superior to the other combinations in the development of swimming speed.

Procedure

This study was conducted during the Spring Semester of the 1969-70 school year. The equipment and facilities used were provided by the Department of Athletics and Physical Education for Men at Sam Houston State University in Huntsville, Texas. The 51 subjects for this research consisted of college men enrolled in three intermediate swimming classes of the required physical education program. Three intermediate swimming classes composed three different groups. One class was designated as Group I; another, Group II; and the other, Group III. The three groups with their respective programs were as follows:

Group I -- participated in the exer-genie training program and the swimming training program.

Group II-- participated in the swimming training program only.

Group III--served as a control group, participating in a regular intermediate swimming class.

The subjects participating in the training programs exercised three days a week for nine weeks. The duration of each class period was 35 minutes. The exer-genie training program lasted approximately 12 to 15 minutes. The duration of the swimming training program was approximately 20 to 23 minutes.

The exer-genie training program included both isometric and isotonic contractions. The subject exerted three 6-second maximum isometric contractions either before or during the isotonic movements against an immovable resistance provided by the exer-genie. The progressive resistive procedure was followed in executing isotonic contractions. The subject exerted maximum effort against the exer-genie at a moderate rate of speed through a complete range of motion. All exercise movements were performed with a resistance that could be moved only three times through the specified range of motion. The 6-second isometric contraction was performed at a specified position during this isotonic movement. The exercises used to achieve the isometric and isotonic contractions were the curl, bench press, and straight arm pull. Each exercise was done for one set with a maximal load for three repetitions.

The swimming training program consisted of swimming the following routine: (1) eight 25-yard sprints at full speed, using the American crawl only, and (2) arm pull for 100 yards, using no leg kick.

Isometric and isotonic strength tests were administered to all the subjects before and after the nine week training program. Isometric strength was measured by the aircraft cable tensiometer, and the 1 RM was used to measure isotonic strength. Both the isometric and isotonic strength tests measured (1) forearm flexion and (2) arm flexion and forearm extension. The swimming speed test was also administered to all the subjects before and after the training period. Each subject, using only his arms, was timed for a 30-yard sprint swim.

Conclusions

The results of the analysis of data from pretest and posttest scores were examined by the pairing design t-test and the Newman-Keuls multiple-range test and are summarized as follows:

1. A combination of the exer-genie training program and the swimming training program improved swimming speed, whereas the swimming training program alone did not improve swimming speed.

2. A combination of the exer-genie training program and the swimming training program increased isometric strength for arm flexion, whereas the swimming training program alone did not increase isometric strength for arm flexion.

3. A combination of the exer-genie training program and the swimming training program did not increase isometric strength for forearm extension and arm flexion more than did the swimming training program alone.

4. A combination of the exer-genie training program and the swimming training program increased isotonic strength for (1) forearm extension and arm flexion and (2) forearm flexion more than did the swimming training program alone, but the increases were not statistically higher.

5. A combination of the exer-genie training program and the swimming training program as well as the swimming training program alone produced a greater increase in isotonic strength than in isometric strength for forearm flexion.

Recommendations

From the results of this investigation, certain implications for training procedures are evident. It appears that a combination of the exer-genie training program and the swimming training program can be recommended as a training program for the arm movement in swimming the American crawl. The basis for this recommendation is that students who participated in the exer-genie training program and the swimming training program increased their swimming speeds, whereas students in the swimming training program only did not improve swimming speed. There is evidence that the increase in swimming speed is due to the exer-genie because students who participated in the swimming training program only did not increase their swimming speeds.

The exer-genie can also be recommended as a means of increasing muscular strength. The basis for this recommendation is that the exer-genie training program and the swimming training program had

higher gains in strength both isotonically and isometrically than did the swimming training program only or the control group.

From the results of this investigation, certain implications for further research are evident. For example, one might study the effectiveness of the exer-genie training program and the swimming training program as a means of developing strength in the legs for improvement of swimming speed. Also, one might investigate an exer-genie training program and a swimming training program that combined both arm and leg exercises as an effective means for increasing swimming speed in the American crawl.

To better determine the effectiveness of one single training method as compared to that of any other training method or combinations of methods, one might use four groups, rather than three; the fourth group could be an exer-genie training program only. Also, larger samples of students in each group should be used to obtain more significant statistical data.

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