THE EFFECTS OF WEIGHT LOADINGS AND REPETITIONS, FREQUENCY OF EXERCISE, AND KNOWLEDGE OF THEORETICAL PRINCIPLES OF WEIGHT TRAINING ON CHANGES IN MUSCULAR STRENGTH

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THE EFFECTS OF WEIGHT LOADINGS AND REPETITIONS, FREQUENCY
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By

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CHAPTER I

INTRODUCTION

Experiments aimed at investigating methods for improving muscular strength by using progressive resistance exercise have been conducted for more than 2,000 years. Milo of Croton, in the Sixth Century before Christ, allegedly practiced weight lifting with a young bull-calf which he lifted each day until it was fully grown. More recently, physical educators have conducted experiments using barbells and specially-constructed apparatus to study strength improvement. Despite these prolonged and concentrated efforts, there is still no generally accepted "best method" for increasing muscular strength.

Statement of the Problem

The problem under consideration involved an investigation of the effects of weight loadings and repetitions, frequency of exercise, and knowledge of theoretical principles of weight training on changes in muscular strength.

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Purpose of the Study

The purpose of this study was to determine the effects of weight loadings and repetitions, frequency of exercise, and knowledge of theoretical principles of weight training on changes in muscular strength. Another purpose was to analyze these effects and determine implications for coaches, physical educators, physical therapists, and others interested in determining the optimum combination of the three variables for increasing muscular strength.

Hypotheses

The tenability of the following hypotheses was tested:

1. Subjects who score above the third quartile on a test of knowledge of theoretical principles of weight training will develop significantly higher levels of muscular strength as measured on the 1-RM bench press than subjects who score below the first quartile on the knowledge test.

2. Groups which train with the three sets of 6-RM will develop significantly higher levels of muscular strength as measured on the 1-RM bench press than groups that train with the two sets of 9-RM.

3. Groups which train three times weekly for one hour each day will develop significantly higher levels of muscular strength as measured on the 1-RM bench press test than groups that train twice weekly for one and one-half hours each day.
Definition of Terms

The terms used in this study are defined as follows:

1. **Weight training** refers to a process whereby the muscle groups are identified and exercised by prescribing specific movement patterns. The subject exercises the muscle or muscle groups and increases the resistance of the exercise by adding weight in small dosages in proportion to his strength improvement.

2. **Repetitions Maximum (RM)** refers to the weight loading and the number of times an individual performs a specific exercise. For example, 9-RM refers to a weight or load which can be raised nine times using maximum muscular exertion. The nine indicates the number of times the weight is raised; the RM indicates that there must be maximum effort. The 1-RM and the 6-RM represent loads that can be raised only once and only six times, respectively, using maximum muscular exertion. Obviously, the 6-RM requires much less weight than the 1-RM.

3. **Sets** are successive rhythmic repetitions of an exercise without an intervening rest period. A set may involve any number of repetitions from one to infinity. For example, a training program requiring three sets of 6-RM requires the subject to perform the exercise for six repetitions on three different occasions with two intervening rest periods.
4. **Theoretical Approach** refers to a process of exposing students to theoretical principles underlying a proposed physical activity before allowing participation in the activity.

5. **Non-Theoretical Approach** refers to student participation in a physical activity without direct classroom exposure to theoretical principles underlying the activity.

**Background and Significance**

The 1968 Olympic Games in Mexico City produced the greatest assault on the record book in the history of the Games. Never before had training and preparation for an athletic contest been more intense. One can only speculate what the results would have been had the Games been held at a more compatible altitude. But even in the thin air at 7,500 feet new records were set in almost every strength and power event and at almost every distance up to 800 meters.

These new Olympic records, along with new marks in National Collegiate Athletic Association track and field events, college football and basketball conference records, and in team and individual sports on all competitive levels, are indicative of the advancements in sports and athletic training that have occurred in the past ten to fifteen years.

The reasons for this ever-increasing rate of record-breaking performances are varied and complex: more people are competing than ever before; coaches are more efficient
at identifying and selecting prospective athletes; improved nutrition, improved health habits, improved facilities and equipment, and more efficient training have played an important part.  

Certainly one of the greatest factors influencing the frequency and number of record-breaking performances has been improved training techniques, one of which has been the development of systematic weight training programs. Although coaches have always recognized the importance of strength in athletic performances, "formal organization and general acceptance of weight training for sports did not occur until the early 1950's." Coaches often encouraged their players to stay in shape and increase in strength during the off-season by heavy manual labor, while at the same time players were instructed not to do any weight lifting. All forms of heavy strength work were thought to slow muscle action. 

Karpovich observed that a half-century ago only wrestlers believed that weight training produced desirable effects.

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4Ibid.
but they abandoned the idea some thirty years ago because it did not contribute to the development of endurance. 5

Since the 1950's, enthusiasm for and use of weight training has been overwhelming; weight training has become an important part of almost all athletic training programs in almost every sport. Two of the world's greatest high jumpers incorporated weight training in their training programs. Valorie Brummel, the great Russian high jumper, devoted 25 per cent of his training time to weight training exercises, while only 14 per cent was devoted to actually jumping over the bar. 6 While we usually think of high jumpers as tall, thin, and rather frail, John Thomas progressed on the press, an arm and shoulder exercise, to the point that he was pressing 165 pounds nine times a day, three days per week, just before establishing the 1960 World Record high jump at 7 feet 3 3/4 inches. 7

The general acceptance of weight training by coaches of all sports on all levels has generated widespread interest in determining the safest and most efficient method for improving muscular strength. But because the number of variables influencing strength increases, it is difficult to design a study which will eliminate the undesirable independent


variables yet make the study broad enough to test the desired hypotheses. Rasch commented that the results of a program of progressive resistance exercises depend upon three variables: (1) the amount of stress placed on the muscle, (2) the duration of the exercise periods, and (3) the frequency of the exercise periods. "The possible combinations of these three factors and the range of human differences in response to each is so great that researchers have hardly scratched the surface of their possible combinations." Ikio and Steinhaus complicated the issue further in the report of their study dealing with the limitations of the expressions of human strength in which they concluded that although strength is a function of the physiologic cross section of the muscle, absolute strength can never be tested because of psychological factors which limit its expression. Karpovich summarized briefly the cumulative research into the effects of weight training in his statement: "Even though muscle training has been practiced since time

9Ibid.
immemorial, and obviously with remarkable success, one may be surprised to discover that there is no complete agreement as to the best method for muscle training.\textsuperscript{11}

Berger\textsuperscript{12} reported that competitive weight lifters train with loads requiring from one to five maximum lifts per set (1 to 5-RM) for as many as ten sets (4 to 10 sets of 1 to 5-RM). For rehabilitating the knee after surgery, Karl Klein recommends a training program of three sets of three-fourths maximum and one set of twenty repetitions with one-half the 1-RM.\textsuperscript{13} Rehabilitation training programs are similar to those of the weight trainer who is interested primarily in improving appearance by making the muscles larger and more definable. "The competitive weight-lifter trains with heavier loads, fewer repetitions, and more sets than the physical therapy patient or weight-trainer."\textsuperscript{14} Research seems to indicate that students without previous experience in weight training should select a program somewhere between

\begin{footnotesize}
\begin{enumerate}
\item Karpovich, \textit{op. cit.}, p. 25.
\item Berger, "Comparative Effects of Three Weight Training Programs," \textit{Research Quarterly}, XXXIV (October, 1963), 396-398.
\item Berger, "Comparative Effects of Three Weight Training Programs," \textit{Research Quarterly}, XXXIV (October, 1963), 396-398.
\end{enumerate}
\end{footnotesize}
that of the competitive weight lifter and the rehabilitation patient.

Many studies have compared the strength improvement effects of various weight training programs. Combinations of number of repetitions, weight loadings, and frequency of exercise have been examined by investigators interested in improving dynamic strength, static strength, and performance as measured by tests of motor ability or athletic ability.

A number of researchers have attempted to identify the best strength training program for college men by designing programs which would allow comparison by multivariate statistical techniques. Berger\textsuperscript{15} and O'Shea\textsuperscript{16} studied the effects of selected weight training programs on the development of strength. Although both studies reported significant increases in strength within all groups, analysis of covariance indicated that mean changes between groups were not significantly different.

In a later study, Berger\textsuperscript{17} found that it was not necessary to work with maximum loads as was reported in the

\begin{quote}
\textsuperscript{15}Ibid.
\end{quote}

\begin{quote}
\end{quote}

\begin{quote}
\textsuperscript{17}Berger, "Comparison of the Effect of Various Weight Training Loads on Strength," Research Quarterly, XXXVI (May, 1965), 141-146.
\end{quote}
previous study. From the results of this study, two conclusions were drawn which have considerable bearing on weight training schedules which are limited to only two days per week. First, he concluded that strength increases will occur after two weeks of training twice weekly with two-thirds or more the 1-RM, provided at least one maximum dynamic effort per week is performed on the third weekly training session; and second, that increases in strength resulting from a training program of one set with two-thirds of the 1-RM, twice weekly, and the 1-RM once weekly, is due primarily to the training with the 1-RM.

The leading investigator in the area of weight training recently summarized the meaningfulness of the research in the area when he reported, "The kind of training program resulting in the most rapid strength increases has not been clearly established."18

The abundance of research produced by investigators interested in the physiological aspects of weight training has not been matched by studies examining the psychological and educational aspects of the activity. A number of studies have compared methods of teaching, student knowledge of progress and knowledge of test results, motivational factors, 

lectures and conceptualizing techniques on acquisition of
skill and achievement in motor ability and physical fitness.
Martin\(^{19}\) and Holt\(^{20}\) examined the effects of grades and
knowledge of results on improvement in physical fitness and
achievement in motor skill learning. While Martin found
that informing students of test results was beneficial only
in the initial stages of the program, Holt concluded that
grade and/or knowledge of results did not cause an increase
in physical fitness.

Cassady\(^{21}\) examined the effects of lectures presented in
required physical education courses as measured by tests of
attitude toward physical education and tests of physical
efficiency. The results indicated that the presentation of
lectures on physical education topics is related to
increased physical efficiency but not to changes in atti-
tudes.

\(^{19}\)Dorothy A. Martin, "Relationship Between Knowledge of
Results and Learning of Motor Skills," unpublished doctoral
dissertation, University of Southern California, Los Angeles,
California, 1965.

\(^{20}\)Calvin S. Holt, "The Effect of Grades and Knowledge of
Results on Physical Fitness," unpublished doctoral disser-
tation, George Peabody College for Teachers, Nashville,

\(^{21}\)Donald R. Cassady, "Effect of Lectures Presented in
Required Programs of Physical Education," unpublished doc-
toral dissertation, State University of Iowa, Iowa City,
Iowa, 1959.
Johnson studied the effect of applying different motivational techniques on changes in muscular strength. He concluded that groups training with knowledge of scores, assigned goal, and taking placebos showed significant strength gains, whereas the non-motivated group realized very little gain.

The related literature may be grouped into two classifications: those concerned with physiological factors, and those dealing with educational factors. Although the studies dealing with the physiological factors have examined a great number of variables, they represent a general consensus. While the studies dealing with educational factors are equally diverse, they are generally inconclusive and indicate a lack of consensus. The literature indicates a need for some very specific investigation of physiological factors, while a much broader approach seems to be called for in examining educational factors. It is the purpose of this study to investigate combinations of programs dealing with both variables.

Limitations of the Study

1. The study was limited to approximately 140 college men enrolled in the weight training courses in the Physical Education Department at North Texas State University during the fall semester of 1969.

2. The study investigated only the effects of knowledge of theoretical principles of weight training, weight loadings and repetitions, and frequency of exercise on changes in muscular strength.

Basic Assumptions

1. It was assumed that the subjects would be honest and cooperative and that they would make a sincere attempt to follow the prescribed training and testing programs.

2. It was assumed that participation in physical activities outside the class would be consistent between groups and that such activity would not influence the results of the study.

3. It was assumed that the effects of different individual instructors would not significantly influence the effects of the experimental methods.

General Procedures

At the beginning of the 1969 fall semester at North Texas State University, eight weight training classes from the twenty-three sections offered were selected to participate in the study. Each of the participating classes was
taught by an instructor interested in the experiment. Each class enrolled about thirty-five students, which provided approximately two hundred subjects in the eight sections. One of eight training programs was assigned at random to each class. The training programs were composed of a combination of two levels of three variables: (1) training two or three times weekly, (2) training with three sets of 6-RM or two sets of 9-RM, and (3) theoretical approach or non-theoretical approach.

Four of the groups received three hours' instruction and demonstrations of the mechanical principles involved in weight training and of the effects of different kinds of training programs on the musculoskeletal system and the vital body functions. During this same initial three-hour period, the four non-theoretical groups recorded anthropometric measurements and performed tests of motor and athletic ability.

After completing the first three hours' instruction and testing, all groups performed the same weight training and conditioning exercises for two weeks. This two-week period provided the subjects equal opportunity to become thoroughly familiar with the training and testing programs. Subsequent changes in test scores could then be contributed to the subjects having increased strength rather than having learned to perform the test from experience. Before beginning the six-week experimental training program, during
which each class trained with a different program, each subject was tested on the 1-RM bench press test. After completion of the six weeks of training, all subjects repeated the 1-RM bench press under the same conditions as the original test.

The tenability of Hypothesis I was tested by using a t test for uncorrelated samples to compare mean changes on the 1-RM bench press test between those subjects scoring above the third quartile with those subjects scoring below the first quartile on an informal teacher-made knowledge test. The tenability of Hypotheses II and III was tested by analysis of the main effects of a 2x2x2 factorial experiment which compared differences of mean change between groups training with three sets of 6-RM and groups training with two sets of 9-RM,
CHAPTER II

REVIEW OF THE LITERATURE

Research studies investigating strength and strength training may be grouped into two major classifications as they relate to the present study: those dealing with weight training and the role of muscular strength in performance; and, those dealing with the effects of knowledge of theoretical principles on motor learning and performance. Examination of the literature dealing with strength and weight training yields four distinctively different types of studies which seem to have developed simultaneously within the past twenty years. Studies dealing with the second major topic, the effects of knowledge of theoretical principles, began at about the same time but are much more widely diversified.

Weight Training

Beginning in the 1930's, a number of studies were conducted in which attempts were made to identify, primarily through factorial analysis methods, some of the physical factors necessary for skillful performance. Factors such as balance, speed, endurance, depth perception, flexibility, speed of movement, and strength were identified. The role of muscular strength was almost always found to be one of the more important factors. These studies accumulated
quickly; and their almost unanimous conclusion—that strength was highly related to performance—probably contributed greatly to widespread acceptance of weight training as a means for improving performance and athletic ability.

Appearing somewhat later were a number of studies dealing with different methods of improving strength and performance. Several of the earlier studies of this classification were conducted primarily by medical researchers interested in rehabilitating sick or injured patients. Thomas L. DeLorme introduced the equipment and techniques of weight training into physical rehabilitation practice during World War II. His work, which led to the acceptance by the medical profession of weight training for rehabilitation, and this newly-gained status of the activity, quickly reduced the opposition of coaches and physical educators to weight training.¹ Although these studies are frequently referred to in the physical education literature, their value may be questionable since physical educators are concerned with improving all-around muscular strength and hypertrophy of healthy subjects.

A third classification includes those studies investigating the effectiveness of isometric training as compared to traditional weight training activities. These studies appeared quite frequently after 1960. Enthusiasm for such

training was probably stimulated by a widely-circulated rumor that much of the success of the 1960 United States Olympic Weight Lifting Team was due to their having included isometrics in their training programs.\textsuperscript{2} A study conducted by Hettinger and Muller in 1958 reported strength gains of 5 per cent resulting from isometric training.\textsuperscript{3} Subsequent studies reported varying results, with some reporting insignificant changes due to isometric training.

A fourth classification of studies began to appear in the literature of the early 1960's. These studies were directed toward determining the most effective method for improving muscular strength through progressive resistance exercises or weight training. These studies dealt with the problem of finding the most efficient combination of weight loadings, repetitions, and frequency of exercise. Because such scientific investigations were in an early stage, a number of inconsistencies in methods, terminology, selection of criterion measures, statistical procedures, and the problem of interpreting results of studies concerned with such a large number of variables have made it difficult to draw anything other than generally broad conclusions.

\textsuperscript{2}Peter V. Karpovich, \textit{Physiology of Muscular Activity} (Philadelphia, 1966), p. 27.

\textsuperscript{3}Karpovich, \textit{op. cit.}, citing Hettinger and Muller.
Strength: A Factor in Performance

Rarick\(^4\) used factorial analysis methods to analyze a battery of athletic and physiological tests to determine whether elements associated with speed of muscular movement could be isolated and identified. Two static strength tests, the back lift and the leg lift, were found to be significantly related to the factor of speed of movement.

A study was conducted by Harris\(^5\) to examine the relationship between force and velocity in various athletic events. Thirteen tests were administered to 163 junior high school girls. Significant correlations were found between static leg strength, static back strength, and seven tests of physical performance including the Sargent Jump, 40-yard dash, broad jump, basketball throw, three-pound shot, twelve-pound shot, and obstacle relay.

Larson\(^6\) found insignificant correlation coefficients between a factor he called gross body coordination and static strength tests of right grip, left grip, back and legs.


Significant correlation coefficients were found between a factor of motor ability and dynamic strength tests of dips, chinning, and floor push-ups. Larson concluded that the motor ability tests yielded high correlations with dynamic strength and comparatively low correlations with static strength.

Larson\(^7\) examined the relationship between static and dynamic strength and motor ability. Dynamic strength was found to be more closely related to dynamic physical performance than was static strength. Larson concluded that dynamic strength was more closely related to motor ability than was static strength.

Rasch\(^8\) studied the relationship of static arm strength to speed of arm movement. The strength of the arm was measured and correlated with the maximum speed of the arm. Speed of movement was measured by a contact chronoscope which was specially designed for this purpose. The strength of the arm was measured by the pull exerted against a

\(^7\)Larson, "A Factor and Validity Analysis of Strength and Variables and Tests, with a Test Combination of Chinning, Dipping, and Vertical Jump," *Research Quarterly*, XI (December, 1940), 82-96.

Chatillions improved spring balance. An insignificant correlation coefficient was found between static strength and speed of movement.

In a study similar to the one mentioned above, Henry and Whitley\(^9\) examined the relationship between static strength and speed of arm movement. A spring scale was used to measure speed of lateral arm adduction. An insignificant correlation was found between static strength and speed of arm movement.

Smith\(^10\) investigated the relationship between static leg strength and performance on the Sargent Jump Test. The use of the arms was restricted, thereby eliminating much of the skill required for performing the jump. Elimination of the arm swing also prevented the influence of transfer of momentum to the jump. Insignificant correlations were found between the vertical jump and static leg strength and a strength/mass ratio.

Richards\(^11\) used 187 subjects to study the relationship between static and dynamic leg extension strength. Static


leg strength was measured with the angle of the leg at eighty degrees. Dynamic leg strength was measured by the amount of load that could be raised once using maximum muscular exertion. A statistically significant correlation was found between static strength and dynamic leg extension strength.

Berger and Henderson\textsuperscript{12} examined the relationship between static leg strength, dynamic leg strength, and leg power. Sixty-six male college students were tested for static and dynamic leg strength and leg power. Relationships between leg power and both static and dynamic leg strength were found to be highly significant, but not significantly different from each other. It was concluded that neither static leg strength nor dynamic leg strength was more related to leg power than the other.

Most of the studies were in agreement that there was a relatively high positive correlation between static strength and physical performance. The correlations were not, however, as high as may have been expected. One study reported an insignificant relationship between static leg strength and the vertical jump. The studies were in general agreement, however, that both static and dynamic strength

were highly related to performance, but that the relationship between dynamic strength and performance was slightly higher than the relationship between static strength and performance.

The significance of differentiation between the two measures, static and dynamic strength, was raised more recently when static training became popular. Subsequent studies have shown that dynamic and static strength are probably not the same; and that static strength tests should be used to measure static strength changes, and dynamic tests should be used to measure dynamic strength changes. This series of studies was important: first, because the studies demonstrated the importance of strength in performance; and second, because they pointed out a need for more specific selection of criterion measures in subsequent studies.

**Improving Strength and Performance**

Dintiman\(^{13}\) studied the effectiveness of flexibility training, weight training, and a combination of weight training and flexibility training for improving running speed. One hundred forty-five subjects participated in one of the three programs. Results showed that both weight training and flexibility training, as supplements to sprint

training, increased running speed significantly more than an unsupplemented sprint training program.

O'Shea\textsuperscript{14} studied the effects of varied short-term weight training programs on improving performances in the 400-meter run. Three groups of thirty subjects each trained for eight weeks with one of three programs: Group A, four sets of 4 to 5-RM; Group B, four sets of 9 to 10-RM; and Group C, four sets of 14 to 15-RM. No significant difference was found between groups on the 400-meter run after eight weeks. O'Shea concluded that any method of short-term progressive weight training involving the large muscle groups of the body is effective for improving performance in the 400-meter run.

Alexander et al.\textsuperscript{15} examined the effectiveness of isometric training for improving performance of shooting of varsity ice hockey players. Eighteen players were randomly divided into two groups. The experimental group trained isometrically for five weeks in addition to regular ice hockey activities, while the control group's activities were identical except for the isometric training. The experimental group showed significant gains in the speed of both


the skating wrist shot and the skating slap shot and in six of eight strength measures. The control group showed significant gains on the skating wrist shot and on one of the strength measures.

Jensen\textsuperscript{16} studied the effectiveness of combinations of swimming and weight training for improving performance in the front crawl. Sixty subjects trained with different combinations of swimming and weight training programs: one group trained with weights; one group trained by swimming; one group swam twice weekly and lifted weights three times weekly; and one group swam three times weekly and lifted weights twice weekly. All treatments resulted in significant improvements, but none of the treatments were significantly more effective than the others.

Lindberg \textit{et al.}\textsuperscript{17} used eighth-grade boys to examine the effectiveness of isometric training for improving performance in broad jumping. Seventy-six subjects were assigned to either a control or an experimental group. The experimental group trained isometrically for six weeks. At

\begin{itemize}
\item \textsuperscript{16}Clayne R. Jensen, "Effects of Five Training Combinations of Swimming and Weight Training on Swimming the Front Crawl," \textit{Research Quarterly}, XXXIV (December, 1963), 471-477.
\item \textsuperscript{17}Franklin A. Lindberg \textit{et al.}, "Effect of Isometric Exercise in Standing Broad Jumping Ability," \textit{Research Quarterly}, XXXIV (December, 1963), 478-483.
\end{itemize}
the end of the experimental period, neither the experimental nor the control group showed significant improvement in standing broad jump ability.

The effects of static and dynamic strength improvement on vertical jump ability were studied by Berger. Eighty-nine subjects were divided into four groups. One group trained with the squat exercise for ten repetitions each session; another group trained with 50 to 60 per cent of the 10-RM for ten repetitions of jumping squats; a third group trained statically at two positions of the squat exercise; the fourth group served as a control. Training took place three times weekly for seven weeks. The two groups that trained dynamically improved significantly more in vertical jump than the group that trained statically.

Zorbas and Karpovich tested 600 subjects on a test of speed of rotary arm movement at the completion of an experimental period in which half the subjects had trained isotonically for six months. Correlations indicated that the weight training group was significantly faster than the group with no experience in weight training.

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Brown and Riley\textsuperscript{20} examined the effectiveness of a single weight training program for improving performance on the Sargent Jump, a leg-lift strength test, and an ankle plantar flexion strength test. Forty Springfield College basketball candidates were divided into two groups. Both groups participated in the physical education activity classes; but the experimental group performed two sets of 10-RM and one set of as many repetitions as possible on a heel-raising exercise. Analysis of mean changes within groups indicated that the experimental group increased significantly on all three tests—the Sargent Jump, a leg-lift strength test, and an ankle plantar flexion strength test. However, although the control group did not make significant increases on either the Sargent Jump or the leg-lift strength test, it did show significant increase in plantar flexion strength.

Masley, Hairabedian, and Donaldson\textsuperscript{21} studied the effects of weight training on strength, muscular coordination, and speed of movement. An experimental group consisting of twenty-four students trained three times weekly for three


weeks, while two control groups were composed of twenty-four students in a volleyball class and fifteen students not enrolled in any activity class. The three groups were tested before and after six weeks of training on tests of speed of movement, muscular coordination, and strength. Both the weight training and the volleyball groups increased significantly in strength, but the weight training group was the only one that improved in speed. The investigators concluded that a greater increase in speed and coordination resulted from weight training than from volleyball or inactivity.

More conclusive evidence supporting the beneficial effects of weight training would be difficult to find. These studies demonstrated that both static and dynamic training will improve performance in such diverse activities as running, ice hockey shooting, swimming, broad jumping, speed of muscular contractions, and vertical jumping. Only one study reported non-significant increases resulting from isometric training. There seems to be a general consensus among the studies that dynamic training may be more desirable than static training when the criterion measure is dynamic strength or performance.
Isometric and Isotonic Programs for Improving Performance

In a study designed to investigate the contribution of increases in muscular strength to changes in speed of movement, Whitley and Smith\(^{22}\) compared isometric-isotonic, dynamic overload, and free-swing training methods. More than 100 college men participated in the training programs for 10 weeks. Although both the isotonic-isometric and the dynamic overload groups improved significantly with the isotonic-isometric gaining slightly greater arm speed, between-group changes were not significantly different.

Dennison, Howell, and Moreford\(^{23}\) examined the effects of static and dynamic exercise programs upon muscular endurance. Ten subjects in each of two groups participated in static and dynamic training programs twice a week for eight weeks. One group performed the Commander Set of static exercises, while the other group participated in a weight training program. Chinning and dipping were used to


measure muscular endurance. Both groups showed statistically significant improvement in chinning and dipping ability.

Belka\textsuperscript{22} compared the effectiveness of isotonic training, isometric training, and combination of the two methods for improving both static and dynamic strength on dominant wrist-flexor muscles. Four groups of five subjects trained three times weekly for five weeks. Maximum static and dynamic strength was recorded at three angles at the end of the treatment period. No significant differences were found between the three experimental groups in changes in static strength, but the combination group made significant improvements which were greater than those of either the static or dynamic groups.

Baer et al.\textsuperscript{25} compared the effects of static and dynamic training on static strength, work capacity, and reaction time. Sixty-three subjects participated in static and dynamic training programs designed to increase the strength of the wrist flexors. The subjects participated in one of

\textsuperscript{22}David E. Belka, "Comparison of Dynamic, Static, and Combination Training on Dominant Wrist Flexor Muscles," \textit{Research Quarterly}, XXXIX (May, 1968), 244-250.

six programs for either a four- or a six-week period. Five of the groups trained dynamically, and one group trained statically. No significant differences were found between the effects of static training and dynamic training on work capacity, reaction time, or static training.

McCraw and Burnam²⁶ compared the effectiveness of isometric, isotonic, and speed training for increasing muscular strength and endurance. Ninety-three university students were assigned one of the three training methods. One group engaged in regular progressive weight training. The second group trained isometrically using five- to ten-second bouts. The third group trained isotonically but used light weights and performed the exercise as quickly as possible. Analysis of the data indicated that a wide range of individual differences existed in strength gains and that no single method is adequate for achieving maximum development of both strength and endurance. The investigators concluded that isotonic exercises were possibly better than either isometric training or speed training for increasing arm strength, particularly among individuals with high initial strength.

Berger\textsuperscript{27} compared the effects of various static and dynamic training programs for improving performance on the vertical jump. Eighty-nine college students were assigned to one of four groups: Group I trained with the 10-RM; Group II trained with 50 to 60 per cent of the 10-RM for ten repetitions of jumping squats; Group III trained statically; and Group IV trained by jumping. All groups trained three times weekly for seven weeks. Berger found that the groups that trained dynamically improved significantly more in vertical jumping than the groups that trained statically or strictly by jumping vertically.

Berger\textsuperscript{28} compared static training and various dynamic training programs and found that training with three sets of 6-RM was superior to the static training group, although the static group was not significantly different from seven dynamically-trained groups. The static training group showed significantly greater increases than the group that trained dynamically for two sets of 2-RM.

Comparisons of the effectiveness of static and dynamic training programs for improving muscular strength have


generally indicated no significant differences. Although a
great number of similarities exist between the training
programs, differences in results seem to be more dependent
on the selection of a criterion measure rather than on any
differences in the training programs. The literature indi-
cates that dynamic training contributes more to dynamic
strength changes than does static training, and that static
training contributes more to static strength than does
isotonic training. This conclusion is consistent with the
correlations reported in the studies in the previous sections.

The research indicates that where dynamic strength,
muscular hypertrophy, and muscular endurance are desired,
isotonic training is superior to isometric training.

Combinations of Sets and Repetitions

Weight trainers and weight lifters have consistently
advocated that the best method of producing muscular hyper-
trophy is to perform many repetitions with little weight,
while the best method of increasing strength is to do fewer
repetitions with greater weight loadings. Barney and
Bangerter\textsuperscript{29} investigated the effectiveness of these two
systems and compared them with a much less strenuous program

\textsuperscript{29}Vernon S. Barney and Flauer L. Bangerter, "Comparison
of Three Programs of Progressive Resistance Exercise,"
advocated by DeLorme and Watkins. Eighty male college students were divided into three groups: Group I trained with three sets of 10-RM; Group II trained with one set of 10-RM, then decreased the number of repetitions and increased weight in five- to ten-pound increments until the 1-RM was reached; Group III performed one set of ten repetitions with one-half the 10-RM, one set of ten repetitions with three-fourths the 10-RM, and one set using the 10-RM. All groups trained for eight weeks. Analysis of variance indicated no significant difference between the three programs for increasing muscular strength, but the DeLorme-Watkins group improved significantly in circumferential gain due to increase in muscular hypertrophy.

O'Shea studied the effects of weight training programs requiring different numbers of repetitions without varying the number of sets. After two weeks of conditioning, thirty subjects were assigned at random to one of three weight training groups. Group A trained with three sets of 9 to 10-RM; Group B trained with three sets of 5 to 6-RM; and Group C trained with three sets of 2 to 3-RM. The three groups trained with the deep-knee-bend lift three times weekly for thirty-five minutes. After six weeks of training,

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the subjects were tested on static and dynamic leg strength. Although all groups increased significantly on both static and dynamic strength measures, analysis of covariance indicated no significant difference between groups. Although the groups were not significantly different, Group B increased most in dynamic strength, with a change of 26.7 per cent, as compared to 21.8 per cent for Group C and 20.4 per cent for Group A.

Berger\textsuperscript{31} compared the effectiveness of three different weight training programs for improving leg extension strength of college men. Three groups trained with either three sets of 2-RM, three sets of 6-RM, or three sets of 10-RM three times weekly. Each group consisted of four subjects. The subjects were tested before and after training for static and dynamic strength. Differences between groups on tests of static and dynamic leg extension strength at the end of training were not significant.

Berger\textsuperscript{32} examined the effectiveness of a traditional weight lifter's training program as compared to a traditional


\textsuperscript{32}Berger, "Comparative Effects of Three Weight Training Programs," \textit{Research Quarterly}, XXXIV (October, 1963), 396-399.
weight trainer's program for improving dynamic strength in a study involving forty-eight college men. Group I trained with six sets of 2-RM; Group II, with three sets of 6-RM; and Group III, with three sets of 10-RM. All groups trained three times weekly for nine weeks. Final results indicated no significant difference in mean changes between groups. Berger concluded that training for nine weeks, three times weekly, with heavy loads for few repetitions per set and numerous sets, is not more effective for improving strength than training with lighter loads for more repetitions per set and fewer sets.

Capen\textsuperscript{33} studied the effects of four different weight training programs on changes in muscular strength. Four exercise programs involving variations in numbers of sets and repetitions were examined. The first program required training with one set of 8 to 15-RM; the second program was the same as the first but required a second set of 5-RM; the third program required three sets of 5-RM; and the fourth program required three sets of 1-RM. Comparisons were made between strength changes resulting from training two, three, four, and five times weekly. The program requiring three sets of 5-RM was found to be most effective.

when used three times weekly. No significant differences were found between groups training with one set of 15-RM for either two or three days per week. The group which trained with three sets of 1-RM was found to be superior to the group that trained with one set of 8 to 15-RM.

In a study designed to determine the minimum amount of work required to produce significant leg strength, Berger compared the effectiveness of exercising for one repetition with various percentages of the 1-RM. Seventy-nine university students participated in one of seven training programs. Three groups trained twice weekly with either 66 per cent, 80 per cent, or 90 per cent of the 1-RM, plus one weekly effort with the 1-RM. A fourth group trained three times weekly with the 1-RM; a fifth group, with 66 per cent of the 1-RM; a sixth group, with the 1-RM only once weekly; and the seventh group acted as a control. All groups trained for six weeks. Results indicated that training with 66 per cent of the 1-RM three times weekly was not adequate for producing strength gains. Training with 66 per cent of the 1-RM twice weekly and with the 1-RM once weekly did, however, produce significant gains. The investigator concluded that significant increases in strength will occur after two weeks of

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training twice weekly with two-thirds or more of the 1-RM, provided at least one maximum dynamic effort per week is performed on the third weekly session. The increases in strength, however, are due primarily to training with the 1-RM.

Berger\textsuperscript{35} studied the effectiveness of training with various programs involving one, two, and three sets, and two, six, and ten repetitions per set. Approximately two hundred subjects were assigned to one of nine programs combining two of the possible combinations of sets and repetitions. The subjects trained three times weekly for twelve weeks. Analysis of variance of difference in mean change between groups on the 1-RM bench press test indicated that three sets and six repetitions per set were best for improving strength when training three times weekly.

Although the previous investigations have shown, in general, that different methods of weight training produced changes in muscular strength, the evidence involves so many different variables that it is difficult to draw anything other than very general conclusions. One study concluded that a program consisting of three sets of 6-RM was slightly better than eight other programs when training

occurred three times weekly. Another study concluded that three sets of 5-RM were more effective than three other programs using different variations in weight loadings and repetitions when training occurred three times weekly. Two studies indicated that training with heavy loads for one repetition (three sets of 1-RM and less) was as effective as training with many repetitions of lighter weights. No similar information was found describing the best method when training occurred only twice weekly. Although one study indicated that only one set of 1-RM was necessary for increasing strength, only two studies examined the specific problem of determining the optimum combinations of sets and repetitions. One study indicated that two to three sets were more effective when training occurred three times weekly. Only one study was found which attempted to determine the most effective weight training program when training occurred only twice weekly.

Knowledge of Theoretical Principles

The second major classification of studies included those dealing with the relationship between knowledge of theoretical principles and performance and the effects of knowledge of theoretical principles on learning motor skills. Although several studies have examined the effects of instruction on learning and performance, Bryan Cratty summarized much of what has been done in his statement,
"Perhaps in no other area has the physical educator been more remiss in producing research."36 Research in the area covers a wide range of topics, including knowledge of intensity of the task, differences in sensory input utilization, placement of formal instruction, manual guidance, and knowledge of mechanical principles; however, a limited number of studies have been conducted in each area.

Hendrickson and Schroeder37 examined the effects of knowledge of theories of refracted light on learning a skill requiring the subject to successfully hit an underwater target with an air rifle. Ninety eighth-grade boys were assigned to either a control group or one of two experimental groups. The experimental groups received instruction on the theories of refracted light prior to learning the skill. One group received more explicit instructions than the other. The control group learned the skill under the same conditions without benefit of knowledge of the theories of refracted light. Both experimental groups learned to hit the target at a depth of six inches more rapidly than the control group. The group with more explicit instructions


learned faster than the other experimental group. However, none of the differences were statistically significant. Similar results were found when the subjects learned to hit the target at a depth of two inches. In this experiment, however, the group with more explicit instructions transferred learning at a significantly higher rate than did the other experimental group or the control group. The investigators concluded that knowledge of theoretical principles was found to facilitate learning skills, and such knowledge improved rates for learning related skills.

Broer\textsuperscript{38} conducted a study to examine the effectiveness of instruction emphasizing problem-solving and student understanding of simplified mechanics prior to learning selected sports skills. Two seventh-grade girls' physical education classes formed the experimental group and received instructions aimed at helping them understand the mechanics of the body and their application to activities of everyday living as well as to sports activities. Instruction in both groups was the same, except that the control group had no instruction in the mechanics of human movement. With less instruction in volleyball and basketball, and an equal amount in softball, the experimental group surpassed the

control group on eight sports skills tests. The mean total-sport skill score of the experimental group was also significantly higher.

Mohr and Barrett\textsuperscript{39} studied the effects of knowledge of mechanical principles on learning intermediate swimming skills. Thirty-one college women students were assigned to either an experimental group or a control group. The experimental group of fifteen women was taught the mechanical principles applying to human movement through water. The control group had the same instructions except for the learning of the mechanical principles. The experimental group made significantly greater improvement in the front crawl sprint, the side stroke power test, and the form ratings for the front crawl, back crawl, and side strokes.

Zuckerman\textsuperscript{40} examined the effects on learning of varying the level of verbalization, personal reference, and phase relationships of picture and sound in films demonstrating the tying of three common knots. One thousand seven hundred eighty-nine Navy Seaman Recruits viewed experimental motion


\textsuperscript{40}John V. Zuckerman, "Effects of Variations in Commentary upon the Learning of Perceptual-Motor Tasks from a Sound Motion Picture," The American Psychologist, V (July, 1950), 363-364.
pictures produced especially for the study. The subjects performed the required task immediately after viewing a film. Results indicated that the most effective level of verbalization was at the medium level and that high verbalization may actually interfere with learning.

Colville studied the effects of knowledge of mechanical principles upon learning a skill. Subsequent learning of more complex skills requiring the same principles was also examined and related to knowledge of the mechanical principles. Three principles were identified: (a) action-reaction; (b) angle to incidence; (c) momentum and gravity. A simple and a complex skill, which were governed by each of these principles, were selected. The experimental groups learned the principles; then they performed the simple, then the complex tasks. The control groups performed the same tasks without knowledge of the principles. The investigator concluded that knowledge of theoretical principles did not facilitate learning of simple skills, nor did it have any transfer effect in learning more complex skills.

In a study designed to determine the relationship between knowledge of weight control and obesity, Canning and Mayer found that obese girls actually knew more about weight control than non-obese girls. A questionnaire involving attitudes toward obesity, food, physical exercise, and knowledge of weight control was administered to 225 obese female adolescents and 213 controls. Despite the greater knowledge of the obese concerning weight control and their more positive attitudes toward exercise, these factors seemed to have little effect in helping them deal with their obesity.

Cassady studied the effects of oral presentation of important concepts of physical education upon the achievements and attitudes of college men. Five hundred fifty-five college men were divided into two groups. The control group and the experimental group participated in identical training programs; but the experimental group listened to six tape-recorded lessons in which were discussed selected objectives, principles, and concepts of physical education.

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The groups were administered the Iowa Physical Efficiency Test at the beginning and at the end of the semester. The mean scores of the experimental group on the physical efficiency test were significantly greater than the mean scores of the control group. The author concluded that the presentation of lectures is related to increased physical efficiency but not to changes in attitudes.

Several studies have examined the effects of knowledge of related principles on acquisition of skills and on transfer of training from task to task. Although there is no general consensus, the results indicate that time and preparation spent in teaching related theoretical principles is beneficial and worthwhile. Only one study was found which examined the effects of knowledge of theoretical principles on changes of tests of physical efficiency or performance. No study was found that studied the effects of knowledge of principles of physiology and weight training on changes in muscular strength.
CHAPTER III

PROCEDURES

Assignment of Experimental Treatments

Instructors of twelve of the twenty-two sections of weight training offered at North Texas State University were informed of the purpose and scope of the research project, and each was offered an opportunity to participate in the study. Of the twelve instructors, eight indicated a willingness to cooperate. To each of these eight classes, one experimental program was assigned according to the procedure for utilizing intact groups described by Underwood et al.¹

The experimental treatments were formulated by determining all possible combinations of two levels of each of three experimental factors according to the formula: $2 \times 2 \times 2 = 8$. Of the three factors—weight loadings and repetitions, frequency of exercise, and knowledge of theoretical principles—frequency of exercise was a real variable and required the selection of four classes that met three times weekly and four classes that met twice weekly.

Since the eight classes were selected specifically to satisfy the frequency of exercise factor, the number of remaining experimental treatments to be assigned to each class was limited to four, or one-half the total number of different treatments. Description of experimental treatments for classes meeting three times weekly and treatments for classes meeting twice weekly were separated, shuffled, placed in separate folders, and then drawn at random and assigned to each class.

The classes were evenly distributed throughout the day, both for classes meeting three times weekly and those classes meeting twice weekly. Of the classes meeting three times weekly, one section met before noon; one section met at noon; and two sections met after two o'clock. Of the sections meeting only twice weekly, two sections met before noon; and two sections met after two o'clock.

Specific group designations and experimental assignments were

Group I trained with three sets of 6-RM at 10:00 a.m. three days weekly and was not exposed to the theoretical principles.

Group II trained with three sets of 6-RM at 12:00 noon three days weekly and was exposed to the theoretical principles.
Group III trained with two sets of 9-RM at 2:00 p.m.,
three days weekly and was not exposed to the theoretical
principles.

Group IV trained with two sets of 9-RM at 3:00 p.m.,
three days weekly and was exposed to the theoretical prin-
ciples.

Group V trained with three sets of 6-RM at 9:30 a.m.,
two days weekly and was not exposed to the theoretical
principles.

Group VI trained with three sets of 6-RM at 2:00 p.m.,
two days weekly and was exposed to the theoretical prin-
ciples.

Group VII trained with two sets of 9-RM at 5:00 p.m.,
two days weekly and was not exposed to the theoretical
principles.

Group VIII trained with two sets of 9-RM at 11:00 a.m.,
two days weekly and was exposed to the theoretical prin-
ciples.

Experimental Treatments

Experimental treatments were composed of three inde-
dependent variables systematically combined in order to allow
a complete factorial experiment. Each independent variable
or factor was divided into two levels. Factor one, frequency
of exercise, was determined by whether the class met two or
three times weekly. Factor two, number of sets and
repetitions, required the subjects to work with different weight loadings. One level required three sets of 6-RM, while the second level required two sets of 9-RM. Factor three, knowledge of theoretical principles, involved a short period of instruction and demonstration relative to the physiology of exercise or no instruction on the topic before beginning training. One level received either two to three class periods of instruction and demonstrations, while the second level did not receive any of the same information by the lecture-demonstration method.

**Frequency of Exercise**

Classes meeting three times weekly began on the hour and concluded at ten minutes before the hour. However, because of the location of the gymnasium and the time required for dressing and showering, actual work time for the classes was only thirty minutes each day or ninety minutes per week. Classes meeting twice weekly began on the hour or on the half hour and concluded at twenty minutes after the hour or at ten minutes before the hour. Actual work time for these classes was 60 minutes per day or 120 minutes per week.
Set and Repetition Training

Each of the eight groups was assigned a specific exercise program identified as either two sets of 9-RM or three sets of 6-RM. Four groups trained with two sets of 9-RM, while four groups trained with three sets of 6-RM. Each group trained with the same series of exercises which included sit-ups, pull-ups, bench press, curl, upright row, inverted leg press, press, and dead lift. Although time did not permit the subjects to perform all the exercises the prescribed number of times, especially in the classes meeting three times weekly, the bench press was always performed first so as to allow the prescribed program to be completed on that lift each exercise day. The exercises were performed in a sequence developed by considering the kinesiological implications of each lift. The sequence allowed the muscle group involved in each exercise a period of rest while exercises which involved other muscle groups were performed. Subjects performing three sets of 6-RM in classes meeting three times weekly had a minimum of ten minutes before repeating a specific exercise. Subjects performing two sets of 9-RM three times weekly had a minimum of fifteen minutes before repeating a specific exercise. Subjects performing three sets of 6-RM in classes meeting twice weekly had a minimum of twenty minutes before repeating
a specific exercise, while subjects using two sets of 9-RM had a minimum of thirty minutes before repeating a specific exercise.

**Theoretical and Non-Theoretical Approach**

The four classes designated Theoretical Approach received instructions and demonstrations relative to physiology of exercise. (See Appendix A.) Classes meeting 3 times weekly received 3 class periods of instruction or approximately 150 minutes, while classes meeting twice weekly received 2 class periods of instruction or approximately 160 minutes. The purpose of the lectures was to familiarize the students with the effects of weight training on muscular strength, hypertrophy, muscular endurance, and cardiorespiratory efficiency. Special emphasis was given to research leading to the selection of the prescribed exercise programs. Subjects were asked to learn specific muscles and muscle groups which were active in each exercise required in the training program. A textbook was assigned at the first class meeting.

The Non-Theoretical Approach groups did not receive any of the information concerning the effects of weight training on muscular strength, hypertrophy, muscular endurance, or

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cardiorespiratory efficiency through lectures or demonstrations. However, they were assigned the same textbook which included some of the same information; and they did receive an explanation of the prescribed training program and an introduction to the proper use of the weight training apparatus.

Description of Subjects

The subjects were 117 men enrolled in one of eight weight training sections offered at North Texas State University in the fall semester, 1969. Forty-two per cent of the subjects were freshmen, thirty-three per cent were sophomores, twenty per cent were juniors, and five per cent were seniors. The average body weight was 163 pounds, with a standard deviation of 24.6. Thirty-seven per cent of the subjects had previous experience in organized weight training programs at North Texas State University. Subjects who were recovering from serious illness or injury or who became ill or injured during the course of the experiment were not included in the data. Subjects who missed more than three class periods during the course of the experiment were not included in the data.

Tests and Testing Procedure

At the conclusion of the organization, orientation, and lecture-demonstration period, and prior to the beginning of
the prescribed exercise program, each subject was tested on the 1-RM bench press test. After two weeks of training, or three and one-half weeks after the beginning of the semester, all subjects were administered an informal teacher-made knowledge test which was constructed especially for the experiment. At the conclusion of the six-weeks' training period, all subjects were retested on the 1-RM bench press test under the same conditions as the initial test.

**Bench Press Test**

The bench press (1-RM) is an Amateur Athletic Union-approved competitive lift. The subject assumes a supine position on a bench which is not higher than eighteen inches. The initial position assumed by the lifter must be maintained throughout the duration of the lift. The lift begins with the barbell resting across the chest and is completed when it is lifted to the point which allows the arms to attain full extension. Before testing, all subjects were allowed to warm up by performing repetitions of approximately 50 per cent of their estimated 1-RM. A minimum of five pounds was added on subsequent lifts until each subject ascertained his 1-RM maximum weight loading for the test. The subjects were allowed a minimum of two minutes between
each lift. Berger and Hardage\textsuperscript{3} reported a reliability coefficient of .98 for the bench press test when determined by the test-retest method.

Knowledge Test

In order to establish content validity of the instrument, the test items were selected according to emphasis given important topics in both the lectures and the textbook. Questions were selected from informal teacher-made tests and from a test manual\textsuperscript{4} for weight training by Philip J. Rasch, which was developed especially for use with the textbook, \textit{Weight Training}, by the same author. From the 146 questions available on the informal teacher-made tests and the 100 questions in the test manual, 51 questions were selected, 26 true-false and 25 multiple choice. Construction of a table of specifications\textsuperscript{5} yielded a summary of content emphasis according to the following percentages: physiological factors, 33 per cent; specific training programs,


\textsuperscript{4}Rasch, Test Manual designed for use with \textit{Weight Training} (Dubuque, 1966).

25 per cent; mechanical and kinesiological factors, 
13 per cent; diets and dietary supplements, 11 per cent; the 
overload principle, 6 per cent; competitive lifting and 
research on weight training, 4 per cent each. Computation 
of the Kuder-Richardson Formula 21 for estimating the 
reliability⁶ yielded a reliability coefficient of .43.

Treatment of the Data

The tenability of Hypothesis I was tested by using a t 
test for uncorrelated samples⁷ to compare mean changes on 
the 1-RM bench press test between those subjects scoring 
above the third quartile with those subjects scoring below 
the first quartile on the informal teacher-made knowledge 
test.

The tenability of Hypotheses II and III was tested by 
analysis of the main effects of a 2x2x2 factorial experi-
ment⁸ which yielded F ratios for analysis of variance for 
differences of mean change between groups training with 
either three sets of 6-RM or two sets of 9-RM and between 
differences of mean change between groups training three 
times weekly and groups training twice weekly.

⁶Ibid., p. 85.


⁸Allen L. Edwards, Experimental Design in Psychological 
Complete computation of the 2x2x2 factorial experiment was carried out in order to examine the interacting effects of all three variables: weight loadings and repetitions, frequency of exercise, theoretical approach versus non-theoretical approach.
CHAPTER IV

RESULTS OF THE STUDY

It was the purpose of this study to examine the effects of three factors on changes in muscular strength: weight loadings and repetitions, frequency of exercise, and knowledge of theoretical principles. Data were collected from university men enrolled in the required physical education weight training courses at North Texas State University. Before beginning a prescribed experimental training program, each subject was administered the bench press test. Each subject was retested under the same conditions after six weeks of training. An informal teacher-made knowledge test composed of questions on the theoretical principles underlying weight training was administered two weeks after beginning the prescribed training program. The data obtained from these tests served as the basis for the findings of the study.

The statistical design, a 2x2x2 factorial experiment, allowed three simultaneous experiments to be conducted with the same group of subjects. Of the 117 subjects who completed the experiment, approximately one-half trained three times weekly, while one-half trained twice weekly; approximately one-half trained with three sets of 6-RM, while
one-half trained with two sets of 9-RM; and one-half listened to lectures and demonstrations of the theoretical principles underlying weight training, while the other half did not receive the lecture-demonstrations.

The systematic arrangement of the experimental factors is presented in Figure 1. Each of the three factors (weight loadings and repetitions, frequency of exercise, and knowledge of theoretical principles) was subdivided into two levels. The number of possible combinations of all levels is represented by the formula: \(2 \times 2 \times 2 = 8\).

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Non-Theoretical Approach

Theoretical Approach

- 3 sets of 6-RM
- 2 sets of 9-RM
- 2 days per week
- 3 days per week

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Fig. 1--Assignments of Treatments for Factorial Experiments.
In order to test Hypothesis I, a Fisher's $t$ ratio was computed to determine the significance of the difference of mean change between subjects scoring above the third quartile and subjects scoring below the first quartile on an informal teacher-made knowledge test. Complete computation of the factorial experiment yielded analysis of variance $F$ ratios for column by column, row by row, and block by block differences. These comparisons were considered main effects and served as the basis for testing Hypotheses II and III. In addition to comparing the main effects of the experiment, the $F$ ratios were also computed for three measures of two-way interaction and one measure of three-way interaction.

Findings Related to the Hypotheses

Hypothesis I stated that subjects who score above the third quartile on a test of knowledge of theoretical principles of weight training will develop significantly higher levels of muscular strength as measured on the 1-RM bench press test than subjects who score below the first quartile on the knowledge test.

The $t$ ratio for the significance of difference of mean change on the 1-RM bench press test between subjects scoring above the third quartile and subjects scoring below the first quartile on an informal teacher-made knowledge test is presented in Table I.
TABLE I

STRENGTH CHANGE IN POUNDS BETWEEN SUBJECTS SCORING ABOVE THE THIRD QUARTILE AND SUBJECTS SCORING BELOW THE FIRST QUARTILE ON KNOWLEDGE TEST

N = 117

<table>
<thead>
<tr>
<th></th>
<th>Mean Differences</th>
<th>SE</th>
<th>t Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above third quartile</td>
<td>16.60</td>
<td>3.20</td>
<td>.040</td>
</tr>
<tr>
<td>Below first quartile</td>
<td>16.73</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The mean change of the high-knowledge group on the bench press test was 16.60 pounds, while the mean change of the low-knowledge group was 16.73 pounds. Calculation of the $t$ ratio for small uncorrelated groups as represented in Table I yielded a ratio of .040, which was not statistically significant. Hypothesis I was not supported by the data and was rejected.

The $F$ ratios for the complete analysis of variance for the 2x2x2 factorial design are presented in Table II. The first three $F$ ratios represent measures of the significance of the difference of mean change on the 1-RM bench press test between the two levels of each of the three main effects. Under source of variation, the test of the significance of the difference between training with three sets of 6-RM and two sets of 9-RM was indicated by the $F$ ratio of .258. The
test of the significance of the difference between training
two days per week and training three days per week was
indicated by the $F$ ratio of 11.416. These two $F$ ratios
served as the basis for either accepting or rejecting
Hypotheses II and III.

**TABLE II**

COMPLETE ANALYSIS OF VARIANCE OF MEAN CHANGE
IN POUNDS FOR $2 \times 2 \times 2$ FACTORIAL EXPERIMENT
$N = 117$

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>d.f.</th>
<th>Mean Square</th>
<th>$F$</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-6RM--2-9RM</td>
<td>27.11</td>
<td>1</td>
<td>27.11</td>
<td>.258</td>
</tr>
<tr>
<td>Theory--Practice</td>
<td>56.45</td>
<td>1</td>
<td>56.45</td>
<td>.536</td>
</tr>
<tr>
<td>3 days--2 days</td>
<td>1201.65</td>
<td>1</td>
<td>1201.64</td>
<td>11.416*</td>
</tr>
<tr>
<td>Sets &amp; Reps--Theory &amp; Practice</td>
<td>51.56</td>
<td>1</td>
<td>51.56</td>
<td>.490</td>
</tr>
<tr>
<td>Sets &amp; Reps--Days</td>
<td>60.75</td>
<td>1</td>
<td>60.75</td>
<td>.577</td>
</tr>
<tr>
<td>Sets &amp; Reps--Theory &amp; Practice--Days</td>
<td>293.74</td>
<td>1</td>
<td>293.74</td>
<td>2.791</td>
</tr>
<tr>
<td>Within</td>
<td>11473.08</td>
<td>109</td>
<td>105.26</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>13195.30</td>
<td>116</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant beyond the .01 level of confidence*
Hypothesis II stated that groups which train with three sets of 6-RM will develop significantly higher levels of muscular strength as measured on the 1-RM bench press than groups that train with two sets of 9-RM. The results did not support the hypothesis. The group which trained with three sets of 6-RM had a mean increase of 16.76 pounds and a standard deviation of 10.50, while the group which trained with two sets of 9-RM had a mean increase of 15.79 pounds, with a standard deviation of 10.70. The F ratio for analysis of variance of mean change between groups was .258 and was not statistically significant.

Hypothesis III stated that groups which train three times weekly for one hour each day will develop significantly higher levels of muscular strength as measured on the 1-RM bench press test than groups that train twice weekly for one and one-half hours each day. The results of the study supported the hypothesis. Groups which trained twice weekly had a mean increase of 12.78 pounds, with a standard deviation of 10.35, while groups which trained three times weekly had a mean increase of 19.21 pounds, with a standard deviation of 9.93. The F ratio for analysis of variance of mean change between groups was 11.416 and was significant beyond the .01 level.
The mean and standard deviation of increase on the 1-RM bench press for all cells and combinations of cells under rows, columns, and blocks is presented in Table III.

**TABLE III**

**MEAN CHANGE IN POUNDS ON 1-RM BENCH PRESS TEST FOR ALL CELLS AND ALL COMBINATIONS OF CELLS UNDER ROWS, COLUMNS, AND BLOCKS**

<table>
<thead>
<tr>
<th>N</th>
<th>Mean</th>
<th>Standard Deviation</th>
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Complete computation of the factorial experiment was carried out in order to test for interacting effects of the three factors: weight loadings and repetitions, frequency of exercise, theoretical approach and non-theoretical approach. Examination of Table III indicates that mean change within groups ranged from an average increase of only 11.07 pounds per group to an average increase of 22.50 pounds per group. The group which trained with three sets of 6-RM two days per week and was not exposed to the theoretical principles had the minimum increase of only 11.07 pounds. The group which trained with three sets of 6-RM three days per week and was not exposed to the theoretical principles had the maximum mean increase of 22.50 pounds. However, the $F$ ratios for two-way interaction were not significant; and the $F$ ratio for three-way interaction was significant only at the .10 level.

The results of the study supported Hypothesis III, that training three times weekly would be more effective than training twice weekly. The results did not support Hypotheses I and II, that subjects scoring above the third quartile on a test of knowledge of theoretical principles of weight training would develop significantly higher levels of muscular strength as measured on the 1-RM bench press test than subjects scoring below the first quartile on the knowledge test, and that subjects who train with three sets
of 6-RM will develop significantly higher levels of muscular strength as measured on the 1-RM bench press than subjects who train with two sets of 9-RM.
CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

"Strength, muscular endurance, and muscular size increase, within limits, in response to repetitive exercise against progressively increased resistance."¹ This is known as the "overload principle" and is the basis for all progressive resistance exercise and weight training programs. The principle involves an infinite number of levels of three variables: the amount of stress placed on a muscle, the duration of the exercise periods, and the frequency of the exercise periods. In addition to these three variables, recent research which investigated factors in motor learning indicates that knowledge of theoretical principles underlying activities requiring motor learning may have some influence on achievement. Because of the number of factors influencing increases in muscular strength, and the varying results obtained from combinations of the many complex variables, there is little agreement concerning the most effective program for improving strength. The purpose of this study was to examine the effects of weight loadings, frequency of

exercise, and knowledge of theoretical principles on changes in dynamic muscular strength.

To investigate this problem, the study was designed to test the following hypotheses:

1. Subjects who score above the third quartile on a test of knowledge of theoretical principles of weight training will develop significantly higher levels of muscular strength as measured by the 1-RM bench press test than subjects who score below the first quartile on the knowledge test.

2. Groups which train with three sets of 6-RM will develop significantly higher levels of muscular strength as measured by the 1-RM bench press test than groups that train with two sets of 9-RM.

3. Groups which train three times weekly will develop significantly higher levels of muscular strength as measured by the 1-RM bench press test than groups that train only twice weekly.

The experiment was designed in such a manner that three experiments were conducted simultaneously with the same group of subjects. Of the 117 subjects completing the study, approximately one-half trained three times weekly, while one-half trained twice weekly; approximately one-half trained with three sets of 6-RM, while one-half trained with two sets of 9-RM; and approximately one-half listened to lectures and
demonstrations on the theoretical principles underlying weight training before beginning training, while the other half did not receive the lecture-demonstrations.

Each of the three independent variables or factors was divided into two levels in order to complete each cell of a 2x2x2 factorial experiment. Factor one, frequency of exercise, was determined by the number of times the subjects trained each week. Classes meeting twice weekly trained for 60 minutes each day, or 120 minutes per week. Classes meeting three times weekly trained for thirty minutes each day, or ninety minutes per week. Factor two, number of sets and repetitions, required the subjects to work with either two or three sets for a total of eighteen repetitions each exercise day. One level required training with three sets of 6-RM, while the second level required two sets of 9-RM. Factor three, theoretical approach versus non-theoretical approach, involved a short period of instruction and demonstration concerning the theoretical principles underlying weight training or no instruction on the topic before beginning training. One level received either two or three class periods of instruction and demonstration before beginning training, while the second level did not receive any of the same information by the lecture-demonstration method. The experimental treatments were formulated by determining all possible combinations of two levels of each
of the three experimental factors according to the formula: $2 \times 2 \times 2 = 8$. Specific experimental assignments were:

Group I trained with three sets of 6-RM three days weekly and was not exposed to the theoretical principles.

Group II trained with three sets of 6-RM three days weekly and was exposed to the theoretical principles.

Group III trained with two sets of 9-RM three days weekly and was not exposed to the theoretical principles.

Group IV trained with two sets of 9-RM three days weekly and was exposed to the theoretical principles.

Group V trained with three sets of 6-RM two days weekly and was not exposed to the theoretical principles.

Group VI trained with three sets of 6-RM two days weekly and was exposed to the theoretical principles.

Group VII trained with two sets of 9-RM two days weekly and was not exposed to the theoretical principles.

Group VIII trained with two sets of 9-RM two days weekly and was exposed to the theoretical principles.

The subjects were 117 men enrolled in one of eight weight training sections offered at North Texas State University during the fall semester, 1969. Forty-two per cent of the subjects were freshmen, thirty-three per cent were sophomores, twenty per cent were juniors, and five per cent were seniors. The average body weight was 163 pounds, with a standard deviation of 24.6. Thirty-seven per cent of the subjects had previous experience in organized weight
training programs at North Texas State University. Subjects who were recovering from serious illness or injury or who became ill or injured during the course of the experiment were not included in the data. Subjects who missed more than three class periods during the course of the experiment were not included in the data. Subjects who failed to complete all three tests were not included in the data.

Each of the eight experimental programs was assigned at random to classes of instructors who indicated a willingness to participate in the study. After completion of the initial organization and orientation periods, four of the sections received the prescribed lecture-demonstrations of the principles underlying weight training, while the four sections not receiving the lecture-demonstrations participated in activities which would not contribute to change in the criterion measure. At the conclusion of the lecture-demonstration period, all subjects were tested on the 1-RM bench press test. On completion of testing, all subjects began the prescribed training program and continued on it for six weeks. After two weeks of training, all subjects were administered an informal teacher-made knowledge test which was constructed especially for the experiment. At the conclusion of the six-weeks' training period, all subjects were retested on the 1-RM bench press test under the same conditions as the initial test,
The tenability of Hypothesis I was tested by comparing the significance of the difference of mean change on the 1-RM bench press test between those subjects scoring above the third quartile and those subjects scoring below the first quartile on the informal teacher-made knowledge test.

The tenability of Hypotheses II and III was tested by comparing the significance of the difference between main effects of a complete 2x2x2 factorial analysis.

Hypothesis I stated that subjects who score above the third quartile on a test of knowledge of theoretical principles of weight training will develop significantly higher levels of muscular strength as measured on the 1-RM bench press test than subjects who score below the first quartile on the knowledge test. The findings did not support the hypothesis. The high-knowledge group's mean increase on the bench press was 16.60 pounds, with a standard deviation of 12.14, while the mean increase of the low-knowledge group was 16.73 pounds, with a standard deviation of 10.55. The t ratio for mean change between uncorrelated groups was .040 and was not statistically significant.

Hypothesis II stated that groups which train with three sets of 6-RM will develop significantly higher levels of muscular strength as measured on the 1-RM bench press than groups that train with two sets of 9-RM. The findings did not support the hypothesis. The group which trained with three sets of 6-RM had a mean increase of 16.76 pounds and
a standard deviation of 10.50, while the group which trained with two sets of 9-RM had a mean increase of 15.79 pounds, with a standard deviation of 10.70. The F ratio for analysis of variance of mean change between groups was .258 and was not statistically significant.

Hypothesis III stated that groups which train three times weekly for one hour each day will develop significantly higher levels of muscular strength as measured on the 1-RM bench press test than groups that train twice weekly for one and one-half hours each day. The findings of the study supported the hypothesis. Groups which trained twice weekly had a mean increase of 12.78 pounds, with a standard deviation of 10.35, while groups which trained three times weekly had a mean increase of 19.21 pounds, with a standard deviation of 9.93. The F ratio for analysis of variance of mean change between groups was 11.416 and was significant beyond the .01 level of confidence.

Conclusions

As a result of the findings of this study, the following conclusions are drawn:

1. Subjects performing prescribed training programs in closely-supervised class situations have limited opportunity to initiate application of knowledge of theoretical principles underlying weight training.
2. Training with heavier weight loadings is not more effective for improving strength than training with lighter loads for the same number of repetitions.

3. The results of a weight training program seem to be more dependent upon the regularity of exercise and the consistency of length of intervening rest periods as required when training occurs three times weekly than upon the specific training program or the total time spent training weekly.

4. The three factors, weight loadings and repetitions, frequency of exercise, and knowledge of theoretical principles, as defined in this study, act independently of one another.

5. Listening to lecture-demonstrations explaining the principles underlying weight training the first two to three class periods has no effect on changes in muscular strength in a six-weeks' period.

Recommendations for the Physical Educator

1. When possible, weight training classes should be scheduled to meet three times weekly rather than only twice weekly.

2. Two sets of 9-RM is less strenuous and requires less time to perform than three sets of 6-RM; therefore, it is recommended that a program requiring two sets of 9-RM be performed in classes meeting either two or three times weekly.
3. Although the results of this study indicate that knowledge of theoretical principles underlying weight training was not significantly related to increases in muscular strength, it is recommended that physical educators continue to include such instruction because of the possibility of transfer of such knowledge to other activities, especially to some of the more strenuous recreational games and sports which may be practiced outside the class and after graduation.

4. Because of the widely varying levels of physiological development among university students, the physical educator should provide an opportunity for students to plan and practice weight training programs based upon sound theoretical principles and relevant to the needs and interests of the individual student.

Recommendations for Further Study

1. Further study should be directed toward determining the most effective combination of sets, repetitions, and frequency of exercise for improving muscular strength, endurance, and hypertrophy.

2. Further research should be directed toward determining the most effective training program for well-conditioned subjects such as those participating in weight training and varsity sports over a period of one year or more.
APPENDIX A

LECTURES

THEORETICAL APPROACH TOPICS

I. INTRODUCTION
   A. Purpose of the experiment
   B. Experiment requirement
      1. Pre-test
      2. Post-test
      3. Knowledge test

II. TRAINING PROGRAMS
   A. Traditional training programs
      1. Body building programs
      2. Weight lifting programs
      3. Rehabilitation programs
      4. Light-heavy and heavy-light programs

III. KINESIOLOGICAL AND MECHANICAL FACTORS
   A. Muscles and levers
   B. Muscle groups and specific exercises
   C. Static strength, dynamic strength, and power

IV. PHYSIOLOGICAL FACTORS
   A. Muscle physiology
   B. Cardiorespiratory efficiency
   C. Fainting
   D. Injuries
   E. Dietary supplements

V. OVERLOAD PRINCIPLE
   A. Overloading cardiorespiratory system
   B. Overloading for muscular endurance
   C. Overloading for muscular strength
VII. RANGE OF MOTION
   A. Forces in angular movements
   B. Gravity and other resistance

VIII. PRESCRIBED TRAINING PROGRAM
   A. Set and Repetition Training
      1. 2 sets of 9-RM
      2. 3 sets of 6-RM
APPENDIX B

PHYSICAL EDUCATION 116

WEIGHT TRAINING

INSTRUCTIONS: Write your name on the answer sheet only. Do not mark on this paper. Select the correct answer and mark the proper space on the answer sheet.

TRUE-FALSE:

1. There are more than 300 muscles in the body.
2. Isotonic contractions require the muscles to shorten during contractions.
3. Isometric contractions require the length of the muscle to remain unchanged throughout the contractions.
4. Food supplements and "health foods" are necessary in addition to the normal adequate diet in order for the weight trainer to insure body growth and to increase strength.
5. The use of progressive resistance exercises to reduce weight is not very successful unless there is rigid control of the dietary intake.
6. Weight training is one of the safest of all forms of physical activity.
7. Increased strength will cause loss of coordination.
8. When training with sets and repetitions, the starting weight for each exercise is fixed and should not be changed from day to day.
9. When training with sets and repetitions, at least fifty pounds should be used as the starting weight for the press since less weight would be a waste of time.
10. Weight training and weight lifting are synonymous terms.
11. The publishers of popular magazines on weight training have made substantial contributions to our understanding of the physiology of weight training.
12. The AMA Committee on the Medical Aspects of Sports has condemned the half squat as "potentially dangerous" to the internal and supporting structures of the knee joint.
13. Rarely are body builders outstanding athletes.
14. The traditional prescription for losing weight is low resistance and high repetitions; for gaining weight, it is high resistance and low repetitions.
15. The reducing diet must contain sufficient vitamins and minerals but be relatively low in calories.
16. The "overload principle" states that strength increases in response to repetitive exercise against progressively increased resistance.

17. A general rule for breathing during weight training is to inhale while contracting the muscles and exhale while relaxing them.

18. Weight training would have the same effect on the athlete's cardiorespiratory system as would an equal amount of time spent jogging.

19. Training methods for increasing strength depend upon the following principle—increasing the amount of stress placed upon the body within the given training period.

20. Some instructors contend that the position assumed in the bent over rowing motion should be avoided because the long lever and the weight of the upper body and resistance place a great strain on the lower back.

21. A simple grip adjustment on a barbell may cause loss of ability to lift because of loss of mechanical advantage of the natural levers within the body.

22. The value of the inverted leg press exercise is questionable since the position is not similar to one normally assumed in performing in sports and games.

23. Set and Repetition training is one of the oldest systems of weight training.

24. Most competitive weight lifters use some type of light-heavy training system.

25. Given ideal lifting conditions, the average college man can lift approximately 1,000 pounds.

26. Weight training courses have been offered for physical education credit at most colleges since the early 1900's.

MULTIPLE-CHOICE:

27. Frequent vigorous exercise causes the heart to (1) beat faster at rest and have less stroke volume (2) beat slower at rest and have greater stroke volume (3) beat faster at rest and have greater stroke volume (4) none of these.

28. A person who exercises frequently is more likely to have (1) a coronary embolus (2) increased capillarization (3) decreased capillarization (4) none of these.

29. When a muscle is exercised, the (1) fibers stretch and become thinner (2) number of fibers increases (3) fibers become thicker (4) none of these.

30. Isometric exercises require (1) lengthening of the muscles (2) shortening of the muscles (3) no change in muscle length (4) none of these.
31. A training program of 3-7 RM would require the trainer to perform (1) 7 sets of 3 repetitions (2) 3 sets of 7 repetitions (3) 21 repetitions per set (4) cannot tell from information given.

32. A training program of 2-7 RM would require a total of (1) 21 repetitions (2) 14 repetitions (3) 2 repetitions (4) cannot tell from information given.

33. A mixed program of 1-20 R1/4RM, 1-10 R1/2M, 1-3 3/4RM, and 1-1 RM requires (1) 1 set of 34 repetitions (2) 3 sets of 7 repetitions (3) 4 sets totaling 34 repetitions (4) 34 sets of 4 repetitions.

34. A good triceps brachi exercise is (1) curl (2) toe rise (3) bench press (4) dead lift.

35. A good biceps brachi exercise is (1) curl (2) toe rise (3) press (4) none of these.

36. A good deltoid exercise is (1) squat (2) dead lift (3) bench press (4) curl.

37. The Olympic Lifts are the two-hand press, two-hand clean and jerk, and (1) two-hand bench press (2) two-hand dead lift (3) two-hand snatch (4) squat.

38. The Power Lifts consist of the dead lift, squat, and (1) curl (2) bench press (3) press (4) one-hand press.

39. The "Valsalva phenomenon" results from (1) a sudden rise in blood pressure, followed by a sudden drop (2) a sudden drop in blood pressure, followed by a sudden rise (3) a sudden and sustained rise in blood pressure (4) none of these.

40. The amount of force that a muscle can exert depends on the number and size of its (1) sarcoplasm (2) sarcolemma (3) myofibrils (4) all of these.

41. The present trend in set training is (1) to use fewer repetitions in each successive set (2) to use more repetitions in each successive set (3) to use the same number of repetitions in each set (4) none of these.

42. Body builders have a tendency to consume a great amount of dietary supplements which are high in (1) carbohydrate (2) protein (3) fat (4) vitamins.

43. Weight training is popular with athletes and football coaches because (1) it provides cardiorespiratory stress (2) it provides muscular stress (3) it is quick and simple (4) all of these.

44. For the average man the most difficult muscles to develop are (1) those of the neck (2) the forearms and calves (3) those of the abdomen (4) the shoulders.

45. A muscle consists of a large number of cells filled with (1) sarcoplasm (2) sarcolemma (3) sarcostyles (4) plasma.
46. Training too frequently will (1) reduce both performance capacity and the ability to resist infections (2) reduce performance capacity but not the ability to resist infections (3) reduce the ability to resist infections but not performance capacity (4) none of these.

47. Normally a man should work out (1) three times a week (2) four times a week (3) five times a week (4) six times a week.

48. The major portion of the diet should be (1) protein (2) carbohydrate (3) fat (4) vitamins.

49. The results of a program of progressive resistance exercise seems to depend upon the following variables: (1) stress placed on muscles (2) duration of exercise period (3) frequency of exercise periods (4) all of these.

50. Only two known deaths have occurred as a result of weight training. In each case the death was the result of a weight falling on a man during practice of the (1) bench press (2) dead lift (3) press (4) none of these.

51. If a muscle is worked regularly the following changes will occur: (1) a permanent increase in the number of capillaries (2) the ability of the muscle to assimilate nutritive materials will improve (3) the size and functional power of the cells will improve (4) none of these.
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Unpublished Materials


