RESISTANCE EXERCISE PROGRAMS ON STRENGTH
AND HYPERTROPHY

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THE EFFECTS OF 10, 20 AND 30 RM PROGRESSIVE RESISTANCE EXERCISE PROGRAMS ON STRENGTH AND HYPERTROPHY

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ABSTRACT

Title

Selected Progressive Resistance Exercise Programs and Their Effects on Strength, Muscle Hypertrophy and Strength Decrement.

Statement of the Problem

The problem consists of three phases: 1) to determine the difference in static and dynamic strength improvements in matched groups training three days per week for three sets each day on selected progressive resistance programs employing the 10 RM, 20 RM, and 30 RM. 2) to determine the effects of these progressive resistance programs on strength decrement. 3) to determine the effects of these progressive resistance programs on muscular hypertrophy.

Methodology

Twelve subjects were selected from a group of thirty volunteers from Michigan State University physical education classes. They were divided equally into three groups matched on static strength of the right quadriceps femoris muscle group as measured by the cable tensiometer. All subjects had normal strength and function of their knees. None had a history of knee injuries. The groups were placed on training programs of 10 RM, 20 RM and 30 RM, respectively, three days per week for a period of five weeks. At the end of the training period, the subjects were again tested on the matching variable, 1 RM strength, hypertrophy, and strength decrement.

Conclusions

The following conclusions are drawn on the basis of the data presented and should be viewed with careful consideration of the limitations of the study.

1. No differences of statistical significance were found between the groups studied in this investigation for static and dynamic strength, strength decrement or muscular hypertrophy.

2. Dynamic strength was improved significantly by all of the training programs.

3. Strength decrement did not shift significantly as a result of any of the training programs.

4. The static strength and muscle hypertrophy results were not significant and were not interpretable.

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CHAPTER I

INTRODUCTION

Progressive resistance exercises as such had their inception in World War II. The urgent need during the war for speedier rehabilitation of the wounded to vacate badly needed hospital beds, led to the development of this type of exercise therapy. However, weight-lifting in some form for various purposes has long been practiced. Much credit for the rapid spread of the progressive resistance exercise program is due to those who appreciated principles of overload training and applied them in their work.

The actual opportunity to first test these principles of exercise arose when a ski trooper who had injured his knee appealed for some sort of treatment that would allow him to remove a long leg brace which he was permanently wearing.[1] He was due for a medical discharge and he desperately wanted to be able to remove the leg brace before his discharge. He had previously received conventional physical therapy for six months consisting of heat, massage, muscle-setting exercises, and the usual quadriceps exercises. The knee did not respond to this treatment and there was no improvement with this type of therapy. Consequently, as a last resort, a program of heavy weight-lifting exercises was undertaken as a possible solution. After a month on this program, all knee symptoms of injury, pain, fluid, and buckling, completely subsided and the knee brace was discarded. The patient could even jitterbug again, much to the amazement of both patient and physician.

With this as its beginning, the progressive resistance exercise program has rapidly grown in scope and effectiveness chiefly because of the interest and aid of the Pope Foundation, and the National Foundation for Infantile Paralysis.[2] These foundations have made it possible to develop equipment and techniques to investigate the effectiveness of progressive resistance exercises in a large number of clinical conditions. Conditions on which these exercises have been investigated are poliomyelitis, muscular dystrophy, scolious, kyphosis, peripheral neuritis and nerve injuries, osteo and rheumatoid arthritis, multiple sclerosis, and following vitallium mold arthroplasties of the hip.[3]

Statement of the Problem

The problem consists of three phases: (1) To determine the difference in strength improvement in matched groups training three days per week on selected progressive resistance exercise programs employing the 10 RM, 20 RM, and 30 RM respectively. (2) To determine the effects of these progressive resistance programs on strength decrement. (3) To determine the effects of these progressive resistance programs on muscular hypertrophy.

Need for This Study

The basic principles of progressive resistance exercise were established empirically by the weight lifters.[4] It has been known for centuries that if a person lifts progressively larger loads, his muscles in response to the work stimulus will increase in strength and size.

It is in fact now a commonly known physiological principle that strength can be augmented significantly by contracting against a degree of resistance that calls forth maximal effort. However, absolute strength does not necessarily mean that the participant has developed either the endurance or speed of movement necessary to do the physical work associated with a specific job or sport. There is very little scientific evidence in regards to the number of repetitions needed for maximum muscle girth and strength increases. Therefore, it was hoped this study might give further insight into the use of progressive resistance exercise for the development of functional strength.

Definition of Terms

One Repetition Maximum (1 RM). The greatest weight that can be lifted once through the full range of extension.

Ten Repetition Maximum (10 RM).* The maximum weight that can be lifted through the full range of extension 10 times.[5]

Cable Tensionmeter.* A small compact unit designed to measure the amount of tension applied to a cable.[6]

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* The same definition is applicable for 20 and 30 RM.
* Manufactured by Pacific Scientific Company, Inc., 1430 Grande Vista Avenue, Los Angeles, California.

Progressive Resistance Exercise. Exercises in which the resistance to contraction is progressively increased commensurate with the subject's muscle power.[7]

Strength Decrement. The loss of strength in a given muscle group resulting from physical exertion.[8]

Bicycle Ergometer. Frictional type of bicycle in which the resistance to pedaling is supplied by friction against the wheel of the bicycle.[9]

Volumometer. A device to measure muscular volume by water displacement.

Limitations of the Study

1. The inability to control the subjects' activity during the week may have had some influence on the results.

2. In some cases, due to conflicting schedules, the impossibility of testing the subjects at the same time of day, may have caused some diurnal variations.

3. Lack of motivation, determination, and belief in self may possibly have affected the results. The sight of a heavy weight on the subject's foot may affect the effort he puts forth.[10]

4. The method used to measure muscular hypertrophy was not sufficiently reliable.

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CHAPTER II

REVIEW OF LITERATURE

It has been recognized for many years that one form or another of heavy resistance exercise provided one of the most effective methods for the development of strength.

DeLorme[1] in 1945, pointed out that the skeletal muscle possessed several qualities, namely, power, endurance, speed and coordination--and that a different type of exercise was needed to develop the desired quality in any particular muscle. He described a system of heavy resistance and low repetition exercises to build up power and volume in the muscles, as opposed to low resistance and high repetition exercises to develop endurance.

The basic principle of progressive resistance exercise is that muscle power is better developed by exercising a muscle a few times at its maximum capacity than by having the muscle repeat an exercise many times against less resistance.[2]

This phenomenon of increasing strength is explained by the principle of overload. A muscle will develop most rapidly in size and strength when its power of contraction is against a maximum load.[3,4,5,6,7]

The Effects of Progressive Resistance Exercise on Strength

Numerous studies have been conducted to show the effects of progressive resistance exercise on strength.

In an experiment by Gallagher[8] who used ten adolescent boys to determine the effect of progressive resistance exercise on strength, it was found that over a period of four months exercising four times a day with hip-knee extension exercises, the mean increase in strength as determined by 1 RM was 49 per cent. No subject in the exercise group failed to increase his 1 RM. The smallest increase was 23 per cent. Likewise, in a control group, none of the subjects increased his 1 RM.

Mc Morris and Elkins[9] applied progressive resistance exercises to the right triceps brachii of twelve varied subjects over a twelve week period. A mean gain in isotonic strength over the twelve week period was 24.5±2.74 pounds or a gain of 59.4 per cent.

Gurevitsch[10] studied the effects of progressive resistance exercise on patients suffering from infantile paralysis. Thirteen experimental patients were placed on an intensive program of progressive resistance exercise and a control group of thirteen patients followed a program of the usual physical therapy applied to infantile paralysis. The experimental group on the progressive resistance exercise program increased in strength more rapidly than the control group.

The power of normal muscles can be doubled in the first four to six weeks of exercise by using progressive resistance exercises. This is supported by evidence brought forth by DeLorme[11] who studied twenty-seven weaker quadriceps muscles and found that fifteen doubled or more than doubled quadriceps power in the first month. The twelve remaining showed improvement ranging from 1 per cent to 89 per cent. These results are believed by DeLorme to compare favorably with the response of normal muscles.

DeLorme's results supports Houtz, Parrish and Hellebrandt[12] in that the single-effort test of strength cannot be used as a criterion of the functional capacity of a skeletal muscle. Others have shown that an actual decrease in work capacity takes place with a large increase in muscle strength.

DeLorme[13] also states that the degree of improvement in power and work capacity is approximately the same for extremely weak muscles as for muscles of greater initial strength, and that the failure to reach normal functional capacity is due to the absence of a normal number of motor units. Results of DeLorme's experiment on poliomyelitis patients were that progressive resistance exercise improved the functional ability of the patients in that they had less difficulty in performances requiring strength and added ability to perform for longer periods without fatigue.

Krusen[14] found evidence, however, that was contrary to DeLorme's. Krusen exercised quadriceps muscles affected by poliomyelitis using resistive exercises and found that on the average muscular strength increased practically as a straight line function over the period of study. The period of study averages about ten weeks depending on the condition of the patients involved. Strength improvement was determined by comparing the initial 1 RM and 5 RM with the final 1 RM and 5 RM. Investigation showed that the gains in strength of the weaker muscles were consistently greater than the gains of the stronger muscles.

Krusen stated that some improvement of muscular strength might be produced by resistive exercises, but that a limit would be reached within the period of the study. However, this limit was never attained; there was no appreciable leveling-off period, even after twelve weeks of training.

Actually, the time required to develop maximum power in the normal muscle, is not known. Professional-strength athletes feel that approximately four years of hard work are necessary to achieve maximum muscle development.[15]

The effect of weight training on athletic power which is related to strength, has been investigated by Chui.[16] In this study, one group of twenty-three subjects performed weight training exercises from two to three times a week for one hour over a period of three months. A control group of twenty-two subjects participated in the required physical education program at the University of Iowa, but did no weight training. Both groups were tested at the beginning and end of the term on the Sargent Jump-standing, Sargent jump running, standing broad jump, eight-pound shot put from a stand, twelve-pound shot put from a stand, and sixty-yard sprint. Chui found a greater increase in all events by the weight trainers than by the control group.

Capen[17] also studied the effect of systematic weight training on power, strength, and endurance. Two groups of students were used.

One was a weight training class of sophomores and the other was a control group consisting of a conditioning class of freshmen all from the University of Tennessee. The classes met twice a week for eleven weeks. Both groups were tested at the beginning and end of the eleven week period on muscular strength, muscular endurance, circulo-respiratory endurance, and athletic power. Batteries of tests were administered to find the above items. Capen found that the weight training group showed greater general improvement in muscular strength than did the control group. There was no significant difference between the two groups in the improvement of muscular endurance or circulo-respiratory endurance. The weight lifting group increased significantly more in speed events than did the conditioning group. It is interesting to note here that the weight training group had no practice in these speed events while the conditioning group had considerable practice.

A more recent study conducted by Capen[18] studied the effects of four different types of progressive resistance exercise programs on the development of muscular strength. The results of this study were that all subjects gained in muscular strength in all four programs, and that the amount of strength that was gained from each of the four programs was found to be nearly equal.

Hettinger and Muller[19] performed seventy-one separate experiments on nine male subjects over a period of eighteen months on the development of strength in muscle in relation to the intensity and frequency of training activities. They concluded the source of the increase in strength is neither the intensity of contraction nor the degree of exhaustion of a muscle fiber, but rather a condition of anoxia within the muscle fiber. The observation that strength grows more rapidly as the training load increases from 1/3 to 2/3 maximal strength is to them only an apparent contradiction. They state that due to the internal arrangement of fibers within a muscle, not all fibers are equally taxed so that not until the training load is about 2/3 maximum are all fibers suffering some oxygen deficit. Hettinger and Muller claim that there is a ceiling on the development of strength in every muscle. This is usually accompanied by pain resulting from some injury within the muscle that stops further increase in effort. They postulate that the maximal strength of any muscle in the body is probably about three times the tension demanded of it in everyday activities.

The Effects of Progressive Resistance Exercise on Muscle Hypertrophy

It is accepted that a muscle under the proper conditions of work, may show a considerable increase in size, as shown by the arm muscles of a blacksmith or the general musculature of an athlete. Zoethout and Tuttle[20] state:

> "The greater size of a trained muscle is caused by hypertrophy of the individual muscle fibers. This increased size of the fiber is attributed wholly to an increase in the amount of sarcoplasm present. An increase in the toughness of the connective tissue which binds the fibers together makes the muscle better able to withstand any additional mechanical demands placed upon it."

An increase in the size of a muscle increases its strength. But the increase in the size of the muscle is not in proportion to the strength gained by exercise. The strength gained by exercise is usually greater than can be accounted for by the increase in the size of the muscle.[21]

A muscle when required to perform heavy work for a protracted interval of time increases in volume. The cause of this has not yet been proven. It is the general opinion that this growth is due to hypertrophy of existent muscle fiber, rather than an increase in their number.[22,23]

In an experiment by DeLorme[24] eight out of eighteen polio patients showed a substantial increase in thigh circumference. These eight were muscles of good strength initially and developed nearly normal power after exercise. No increase in thigh circumference was found in several impaired subjects.

DeLorme's initial view of hypertrophy was that in order to obtain rapid hypertrophy, the muscle must be subjected to strenuous exercise and at regular intervals to its maximum exertion.[25] However, Hellebrandt and Houtz[26] state, "The mere repetition of prevailing performance does not lead to the hypertrophy of skeletal muscles. Hypertrophy appears only when the rate of working is increased."

Siebert[27] with rats, also demonstrated that the mere repetition of prevailing performance does not lead to the hypertrophy of skeletal muscles. Hypertrophy appeared only when the rate of work was increased. It seems that power was the decisive factor, not the total amount of work done.

Thus far, little has been said about the nature of the changes occuring in the machinery of the human body by which the ability to perform work is enhanced. The rapidity with which overload stress increases the capacity for strenuous exercise suggests that this must be due to changes in the central nervous system and not to alterations in anatomical structure.

It appears that too much attention has been placed on the contractle tissue and not enough on the mechanisms which drive the skeletal musculature.

From his initial view on hypertrophy, DeLorme since has changed and advocated that, "Fewer repetitions permit exercise with heavier muscle loads, thereby yielding greater and more rapid muscle loads, thereby yielding greater and more rapid muscle hypertrophy."[28] No systematic attempts, however, have been made to test this hypothesis. "Reasoning from first principle suggests that some point must exist below which reduction in the dosage of exercise defeats the purpose for which it has been administered."[29]

The principle of overload is as important in the rehabilitation of the disabled as it is in the training of athletes. Limits of performance must be persistently extended to restore the function of muscles. The rate at which improvement progresses depends on the degree to which the person is willing to overload. Hellebrandt and Houtz[30] conducted 620 experiments on 17 normal adult subjects on the mechanisms of muscle training in man. Their conclusions were as follows:

1. Strength and endurance increase when repetitive exercise is performed against heavy resistance.
2. The slope gradient of the training curve varies with the magnitude of the stress impaired, the frequency of the practice sessions, and the duration of the overload effort.
3. Mere repetition of contractions which place no stress on the neuromuscular system has little effect on the functional capacity of the skeletal muscles.
4. The amount of work done per unit time is the critical variable on which extension of the limits of performance depends.
5. The speed with which functional capacity increases suggests that the central nervous system changes contribute an important component to training.
6. The ability to develop maximal tension appears to be dependent on the proprioceptive facilitation with which overloading is associated.
7. No evidence was forthcoming in support of the validity of currently popular techniques of administering progressive resistance exercise clinically.

At best, the increased area of the extremity is a rough estimate of hypertrophy of a muscle contained therein. Without microscopic studies, the only present means of measuring hypertrophy is indirectly either by volumetric studies of an extremity, by calipers or by girth measurements.

Several studies have been completed in an attempt to show the effects of progressive resistance exercises on muscle girth and the amount of increase that takes place.

McMorris and Elkins[31] applied progressive resistance exercises over a twelve week period to the right triceps brachii of twelve normal subjects, nine male and three female, aged 20-29 years. Circumference measurements of the arm were taken preceding the exercise, at six weeks, and at the termination of the training program.

Measurements were taken with a steel tape and done by the same examiner. The mean gain in circumference was 3.1 per cent.

McGovern and Luscombe[32] after modifying DeLorme's and Zinovieff's methods of progressive resistance exercises in an attempt to reduce the time required by these methods, found that in all experiments, measurements of thigh girth were of no significance. In all groups tested, thigh girth increased in some subjects, and decreased in others. They believe that this is related to change of individual difference in subcutaneous and fat deposits and not related to muscle substance. It was felt by these authors that their modifications produced results in terms of strength gain that are equal to those of the original procedure.

In a particular technique of progressive exercises by Zinovieff[33] (The "Oxford Technique,") carried out on fifty-five consecutive out-patients with weak quadriceps muscles, the average increase in muscle volume was 3/8 inch every 2½ weeks. The "Oxford Technique" involves the same principle of heavy resistance and low repetitions to develop maximal strength but after each bout of ten lifts, weight was reduced instead of increased to approximate the fatigue in the muscles, yet the muscle was exercised to its maximum of capacity.

Gallagher[34] found that thigh measurement showed a mean increase of approximately 7/8 inch for members of an exercise group using progressive resistance exercises on a knee extension program four times a week for four months. No member of a control group showed an increase in muscle girth.

The Volumometer as a Test of Hypertrophy

Very little has been done using the volumometer as a test of muscle girth. The first modern volumometer for the human body was Spivak's[35] developed in 1915 in Denver. Sixteen men were tested, the volume was obtained by direct immersion. The increase in the level of the water permitted the calculation of the volume of water displaced by the body. The tank had an outside glass tube graduated in centimeters and millimeters. It was entered by means of a step ladder, the water level being carefully read before and after immersion. The reliability of this instrument was not given.

The volumometer or any other clinical measurement of muscle girth has many variable factors that must be taken into consideration when measuring the circumference of an extremity. Yet, measuring the circumference of a limb is the most common means used clinically to determine hypertrophy or muscle growth. Among the many variables are; the "amount of subcutaneous tissue, the state of hydration, the amount of vasodilation, the state of development of other included muscles and the muscle length".[36]

Strength Decrement

The Strength Decrement Index has been proposed as a test of muscle fatigue. The basic concept of this test is that an immediate effect of fatiguing muscles is to reduce their ability to develop tensions.[37]

The formula for strength index is:

$$SDI = \frac{Si-Sf}{Si} x\ 100$$

When:

Si Initial strength; taken before exercise

Sf Final strength: taken after exercise.[38]

Clarke[39] demonstrated the effect of strength decrement and fatiguing exercise on the elbow flexor muscles. He found the immediate effect of muscular fatigue is to reduce their ability to apply muscular tension, the degrees of muscular fatigue are reflected in changed strength scores. Cable-tension elbow flexion strength tests were given each subject 30 seconds after the exercise, and again at intervals of five minutes to determine the strength recovery. The initial drop at 30 seconds after exercise was 29 to 32 per cent of pre-exercise strength.

Muscles under physical stress may weaken when carrying loads. This was clearly demonstrated by Clarke.[40]

When conditioned, however, subjects experience less strength loss as measured by a lower strength decrement index.[41] The strength decrement of men carrying various army packs on military marches was studied. They found the physical condition of the subjects improved as a result of repeated pack-carrying marches. This factor was reflected in lessened strength losses for the late marches in the series. As a result of these studies, the Strength Decrement Index was proposed as a test of local fatigue of muscle groups.

In the performance of even simple motor acts, the element of learning plays an important part and probably contributes to the increased ability to exert a maximum effort. At the time of initiation of exercise, the influence of learning is the lowest, and strength measurements taken at this time often reveal considerable lower values than measurements taken a few days later. This early improvement in strength would appear to be due to motor learning.

Measurable strength loss then results from exhaustive exercise. The amount of weight required to induce exhaustion in a short time depends on the strength of the included muscles. The work output of muscles in exhaustion performances is greater when in position to apply greatest strength at the point of greatest stress.[42]

> "Muscle fatigue is accompanied by loss in ability to develop tension; the amount of this loss can be measured, or this amount varies in relation to the degree of fatigue, the proportionate strength loss may be utilized as an indicator of the amount of fatigue."[43]

<u>Cable Tensiometer</u>

The cable tensiometer is a device for measuring strength. A review of the literature by Daniels, Williams and Worthingham[44] on strength testing techniques indicates that nearly all tests developed between 1912 and 1946 were dependent upon the subjective judgment of the examiner as he estimated the ability of the muscle to overcome gravity and outside force. In view of the lack of objectivity of strength tests, Clarke[45] examined several different types of instruments to find the one most applicable for measuring muscle strength.

The cable tensiometer was found to be superior for this purpose.

In using the cable tensiometer as a test for strength, one of the difficulties in administering the test is to isolate the effect of the muscles controlling the specific joint movements and to eliminate the effect of compensatory muscles. When considerable care was taken in administering the test and specific instructions were followed, Clarke[46] found the objectivity coefficient of this test when used to test the strength of the quadricep muscles by extension of the leg at the knee joint to be .94. The accepted standard of objectivity is .90.[47]

Clarke and Elkins[48] found the best position for testing the quadriceps is in a sitting position leaning backward with the arms extended to the rear and the hands grasping the sides of the table. The leg is best tested at 115 degrees of extension.

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CHAPTER III

METHODOLOGY

Introduction

The present study was undertaken to determine the effects of three different progressive resistance exercise programs on dynamic and static strength, muscular hypertrophy and static strength decrement. The test battery used consisted of the 1 RM to measure dynamic strength,[1] a volumometer to measure musclar hypertrophy by water displacement[2] and a cable tensiometer to measure static strength.[3] Twelve subjects were selected from physical education service courses at Michigan State University and matched on static strength scores.

Prior to and after their respective training program, the subjects were measured for static and dynamic strength, muscular hypertrophy and strength decrement of the right quadriceps femoris muscle group. The training program consisted of ten, twenty, and thirty RM, respectively. The superiority in the amount of muscular strength gained when participating in a program of progressive resistance exercises three days a week rather than five yields a probablility of six per cent.[4]

Experimental Design

Twelve subjects matched into three groups on the static strength of the right knee extensors were selected from a large number of students measured from the physical education service courses at Michigan State University. All subjects had normal strength and function of their knees. The groups were randomly placed on training programs of 10, 20 and 30 RM three days per week for a period of five weeks. Subjects were tested prior to (T_1) and following the training program (T_2) on the matching variable, 1 RM strength, hypertrophy, and strength decrement.

Training Programs

Each subject, regardless of group, performed three sets of repetitions resting two minutes between sets. The muscle group tested was the right quadriceps femoris muscle by means of a knee extension movement. The movement was performed by extending the leg completely from 90 degrees flexion to 180 degrees extension. Progressive resistance was applied by means of a boot strapped to the foot with attachable barbell plates ranging in weight from 2½ pounds to 25 pounds.

The initial resistance used was based on percentages of 70%, 60% and 50% of the 1 RM which corresponds roughly to the 10, 20 and 30 RM respectively. Adjustments were then made to obtain the exact RM for each subject. Extreme care was taken to make sure that the maximum load for the number of repetitions was being executed.

For example, in the 10 RM program, if the subject could lift the weight 11 times, weight was added before starting the second set.

No change was made for the third set. If the subjects could lift the weight only 9 times, weight was not removed until the next training day when he would start with a slightly lighter load. If the subject could lift only the prescribed number of repetitions and no more, weight was added the next training day.

In most cases, when two or three bouts of exercise are executed, only one need be pitched to the level of maximal effort to give a maximum gain in strength in a minimum amount of time.[5] In fact, only "one-half to two-thirds of the contractions performed require less than maximal tension".[6]

The exercise performed was repetitive. The motion of the leg from flexion to extension by each subject was kept constant by executing the exercise to the rhythm of a metronome. This eliminated jerking movements and any advantages that might be gained by an uneven or speedier movement. The cadence was kept constant throughout the experiment.

To control the total number of correct movements during a set of repetitions, an apparatus was used which indicated when the knee was fully extended (Figure 1). On completing 180 degree extension, the subject received credit for a complete repetition when his foot was within three inches of this apparatus. When executing a movement, the buttocks had a tendency to rise off the table, thus lowering the foot slightly. To compensate for this tendency, three inches was selected arbitrarily as close enough to be considered a complete repetition.

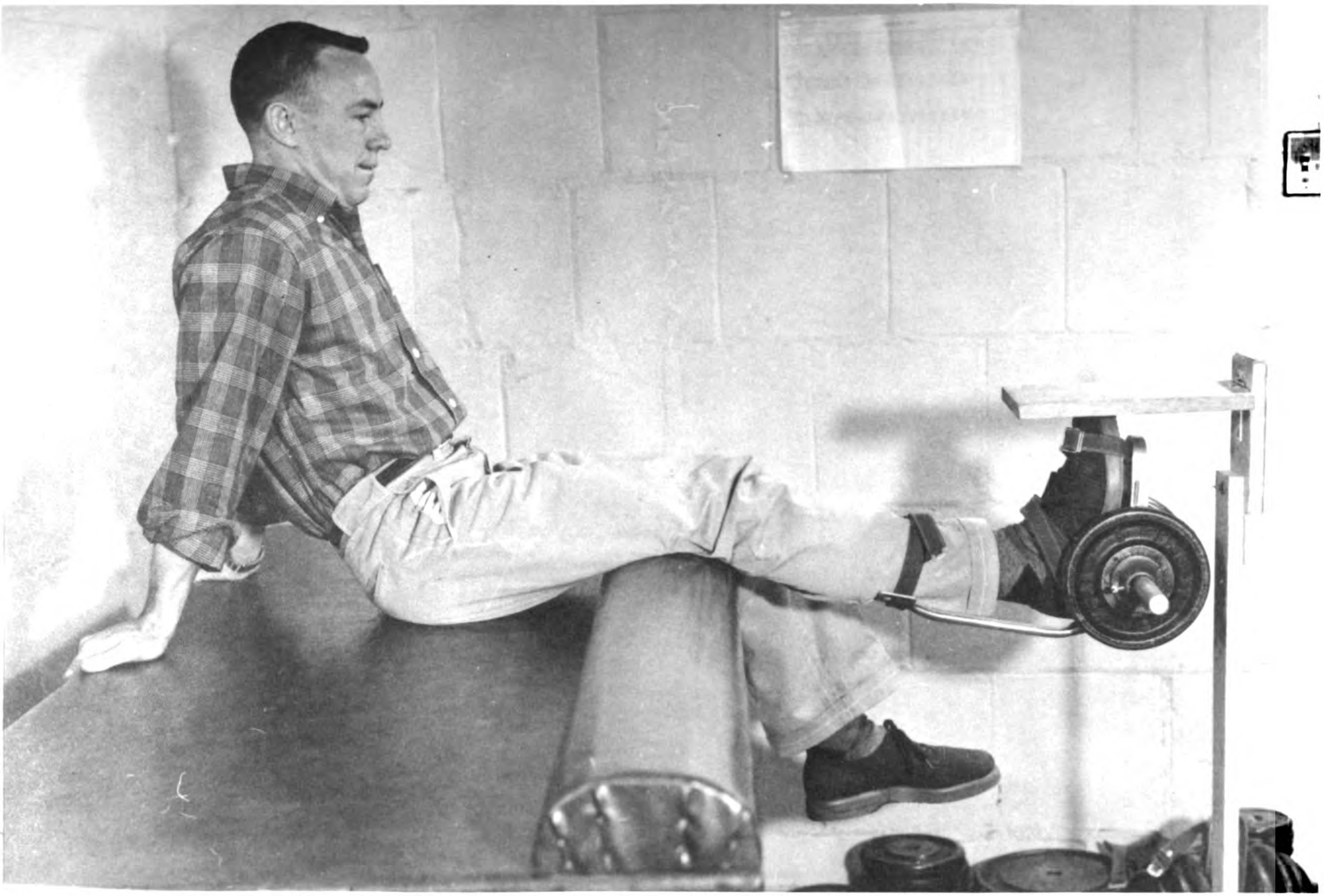

Figure 1. Completion of a Correct Movement.

The maximum repetition a subject was able to perform with a particular resistance was the repetition following the last movement in which contact was made with the apparatus.

To further eliminate errors, a hand counter was used to count all repetitions and the total number was recorded after each set. A Kodak Timer was used to keep the two minute interval constant between rests.

Testing Techniques

Dynamic Strength. The one repetition maximum (1 RM) as described by DeLorme[7] was used as the test of dynamic strength.

Static Strength. Determined by use of the cable tensiometer as described by Clarke.[8]

Static Strength Decrement. Determined by using the cable tensiometer to measure static strength then riding a friction bicycle ergometer twenty miles per hour with six and one-half pounds of resistance until pace could no longer be maintained. Thirty seconds after completion of the ride, the static strength was again measured. The difference between the two measurements was considered to be strength decrement.

Clarke's[9] tensiometer procedures were followed. Karpovich[10] describes the use of the friction bicycle ergometer in greater detail.

Muscle Hypertrophy. A specially constructed volumometer (Figure 2) was used to measure the volume of the right leg by water displacement before and after the five week training period. The

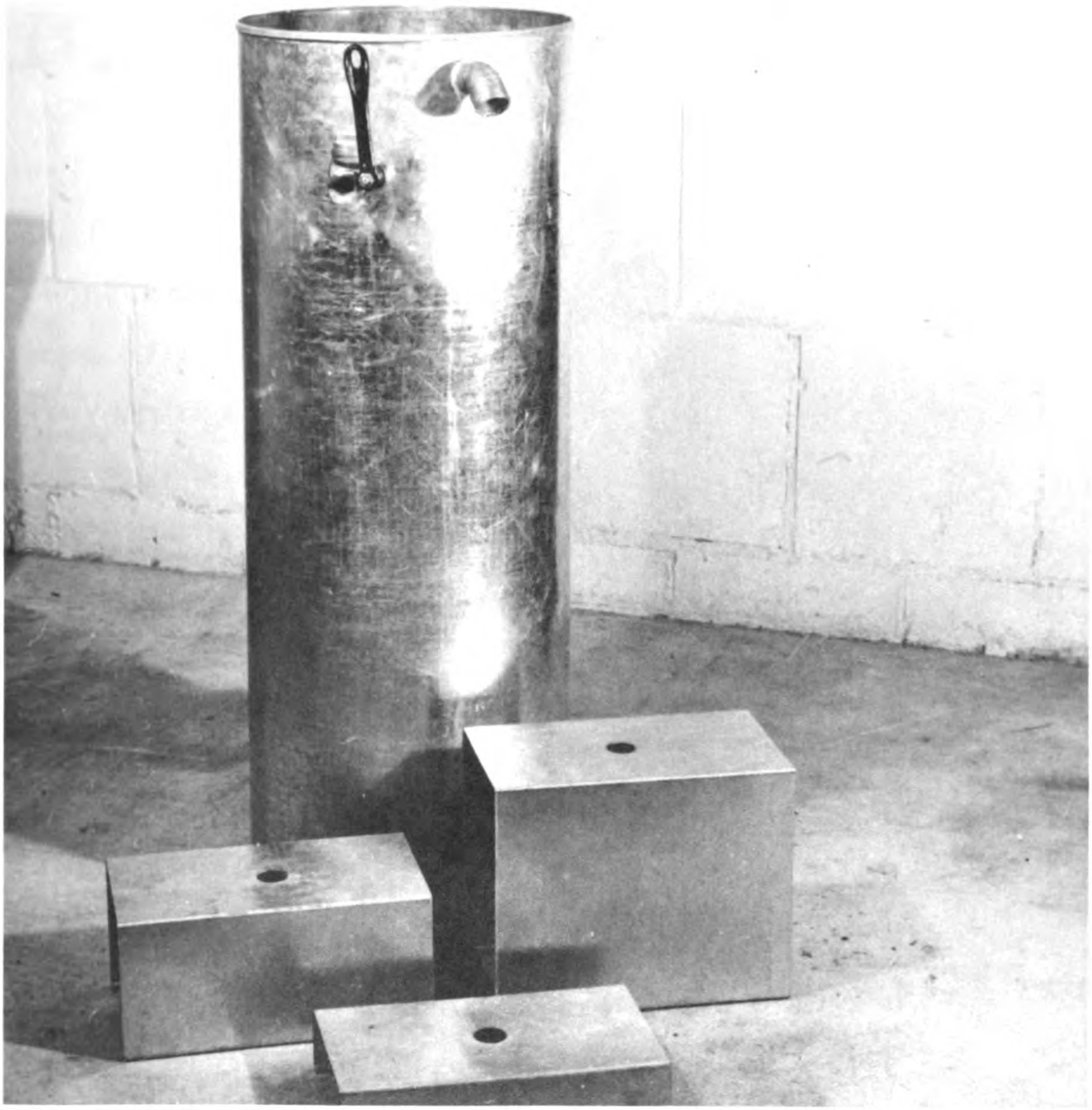

Figure 2. Volumometer.

volumometer was constructed just large enough to comfortably contain a subject's leg. It consisted of two outlets. One a "cut off" valve and the other an overflow spout. The tank was filled with water to the "cut-off" valve and allowed to overflow until the water stopped dripping. The valve was then closed and the subject placed his right leg in the tank. The water displaced through the overflow spout was caught in a glass beaker and then weighed on a scale broken down into grams. Paraffin was placed in the outlets to cut down the drip. The water was kept at body temperature to eliminate changes that occur when a muscle is subjected to a sudden temperature change.

A one, two or five inch block was placed in the bottom of the tank depending on the length of the subject's leg. This was to standardize the amount of volume that was placed in the tank each time. The subject's body weight was also recorded before and after the training program. The reliability of the volumometer as determined by the test re-test method of correlation on 30 cases was .21.

Methods of Statistical Analysis

The student "t" test of significance[11] was used on the initial to final test data for each group.

For all measures analysis of variance[12] was used to compare the differences between groups.

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CHAPTER IV

PRESENTATION AND ANALYSIS OF DATA

The subjects in this study were individually matched in static strength and divided into three groups. Each group participated in knee extension progressive resistance exercise training programs three times a week for five weeks. The 10 RM, 20 RM and 30 RM respectively were employed for the three groups. The effects of the training programs on strength and hypertrophy are compared in this chapter.

Analysis of Data

The pre-training (T_1) to post-training (T_2) data for all measures were compared using the Student "t" test of significance.[1]

To compare the differences between the 10 RM, 20 RM and 30 RM groups, the analysis of variance technique was calculated.[2]

For each group, prior to and following training, static strength was measured with the tensiometer and recorded. Dynamic strength was determined by the 1 RM and recorded. Strength decrement and muscle hypertrophy were also measured before and after the 5 week training period.

Results

Strength. The mean difference from T_1 to T_2 in dynamic strength improvement was statistically significant beyond the 1 per cent level in the 10, 20 and 30 RM groups (Table I). In static strength, the

TABLE I

INITIAL TO FINAL TESTING RESULTS

10 RM GROUP	MEAN T_1	MEAN T_2	MEAN DIFFERENCE	t
1 RM (lbs.)	60.8	100.6	39.9	10.9*
Static Strength (lbs.)	213.1	313.1	100.0	1.84
Decrement (lbs.)	14.4	-28.8	43.1	3.0
Hypertrophy (gm.)	3226.0	3433.0	207.0	3.7**
20 RM <u>GROUP</u>				
1 RM	58.3	101.3	43.0	15.6*
Static Strength (lbs.)	213.3	296.9	83.6	3.2**
Decrement (lbs.)	27.6	-18.1	-45.8	1.7
Hypertrophy (gm.)	2640.8	2737.6	96.9	1.8
30 RM <u>GROUP</u>				
1 RM	70.3	99.4	29.1	6.7*
Static Strength (lbs.)	211.9	276.9	65.0	3.4**
Decrement (lbs.)	21.9	1.3	-20.6	1.0
Hypertrophy (gm.)	2447.7	2758.8	311.2	3.6**

* Significant at the 1 per cent level.
**Significant at the 5 per cent level.

mean difference from T_1 to T_2 was statistically significant at the 5 per cent level in the 20 and 30 RM groups, but was insignificant in the 10 RM group.

The improvements in static and dynamic strength in the 10, 20 and 30 RM groups, however, were not significantly different ($F=3.794$, $P=$ greater than 5 per cent; $F = .444$, $P =$ greater than 5 per cent, respectively). Though insignificant, dynamic strength improvement was greatest in the 20 RM group (Table II). The 10 RM group had a greater increase than the 30 RM group. The present data seem to support those of Berger[3] in that there appears to be an inverse relationship between dynamic and static strength improvement. The significant static strength results for the 20 and 30 RM groups are the first in the Michigan State University laboratory. It is important to note, however, that the programs evaluated are not significantly different.

Strength Decrement

The differences in strength decrement between the 10, 20 and 30 RM groups (Table II) were not statistically significant. The differences from initial to final tests were not statistically significant (Table I) for each of the groups. Before training, all three groups showed improvements in strength following the bicycle ergometer ride. After training for five weeks, however, all three groups showed a decrement in static strength. Before training, the 20 RM group had the greatest increase in strength after the fatiguing

TABLE II

ANALYSIS OF VARIANCE RESULTS:

DIFFERENCES BETWEEN GROUPS, INITIAL AND FINAL TEST DATA[!]

MEASURE	MEAN DIFFERENCES, $T_1 - T_2$			F	Critical F Value (5% Level)
	10 RM	20 RM	30 RM		
Dynamic Strength (lbs.)	39.9	43.0	29.1	3.8	5.1
Static Strength (lbs.)	100.0	83.6	65.0	.4	5.1
Decrement (lbs.)	43.1	-45.8	-20.6	3.4	5.1
Hypertrophy (gm.)	207.0	96.9	311.1	2.5	5.1

! Analysis of variance tables for each analysis are in Appendix B.

exercise, followed by the 30 RM group and the 10 RM group. After training, the 20 RM group had the largest decrement followed by the 10 RM and the 30 RM. These differences, however, were not statistically significant.

Hypertrophy

In the 10 and 30 RM groups, there were significant differences between initial and final test results on the right leg (Table I). The 20 RM groups data were not statistically significant. The 30 RM group showed the greatest increase in muscle size. Between the three groups, the differences were not statistically significant (Table II).

Discussion

The results of the 10 RM strength improvement may have been biased due to conditions beyond the author's control. One of the subjects in this group was in the hospital during the last week of the experiment and missed two days of training. Another subject in the same group had completed two hours of R.O.T.C. drill just prior to being tested on dynamic strength. It was felt by the writer that the latter subject should have done much better on his 1 RM test. These two factors may account for the poorer showing in dynamic strength in the 10 RM group.

The results of this study show a trend between static and dynamic strength improvement (See Table I). With more repetitions and a lighter load, the mean static strength was less in each group. The 20 and 30 RM groups, though showing less improvement, were both

statistically significant in the initial to final test data. The dynamic strength data are not clear due to the bias in the 10 RM results.

These data seem to indicate a poor relationship between strength and endurance. Though the differences between groups were not statistically significant, the 20 RM group had the greatest increase in dynamic strength and the greater decrement at the end of the training period. The 10 RM group had the next greatest increase in 1 RM and the next largest decrement followed in the same manner by the 30 RM group. The stronger subjects seemed to have less endurance. This was also evident before training. It is interesting to note that before training, all but one subject had an actual increase in strength after the fatiguing exercise. While after the training period, all but two subjects had considerably large decrements. This may be due to warm up factors. (See Appendix A)

However, since there were no significant differences within groups nor between groups in strength decrement, it should not be assumed that the testing technique used for this purpose was not sufficient. Before any definite assumption can be drawn regarding the effects of various progressive resistance exercise programs on strength decrement, a range of loads should be investigated.

It is felt by the writer that the test of hypertrophy with some improvement in the testing techniques would become a fairly reliable instrument. Even with its poor reliability of .21, however, there were definite shifts in hypertrophy. All but the 10 RM group showed

statistically significant increases in muscular girth.

Statistically significant differences between groups in all measures may not have taken place because the training time involved was not sufficient. Since most measures had significant increases within groups after training, this may have also occurred between groups had the training period extended over a longer period of time. The opposite is just as likely, however, in that the training programs may not have been sufficiently different to produce statistically significant results, particularly in view of the rather rough 1 RM, hypertrophy, and strength decrement techniques of measurement.

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CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The purpose of this study was to determine the effect of 10, 20, and 30 RM progressive resistance exercise programs on strength and hypertrophy. Three groups of four subjects each matched on static strength respectively employed 10, 20 and 30 RM programs of progressive resistance exercise three days a week for a period of five weeks. Testing for each of the measures was completed prior to and immediately following the five week training period.

Conclusions

The following conclusions are drawn on the basis of the data presented and should be viewed with careful consideration of the limitations of the study.

1. No differences of statistical significance were found between the groups studied in this investigation for static and dynamic strength, strength decrement or muscular hypertrophy.

2. Dynamic strength was improved significantly by all of the training programs.

3. Strength decrement did not shift significantly as a result of any of the training programs.

4. The static strength and muscle hypertrophy results were inconsistent and were interpretable.

Recommendations

1. It is recommended that a similar study be made over a longer period of time and with more subjects.

2. When determining strength decrement for further studies, a range of loads should be used.

3. A better technique of measuring muscular hypertrophy should be developed before attempting to measure growth of muscle girth in future studies.

4. Additional studies should be made to determine the relationship between static and dynamic strength.

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APPENDIX

MICHIGAN STATE UNIVERSITY
DEPARTMENT OF HEALTH, PHYSICAL EDUCATION, AND RECREATION

GRADUATE STUDIES AND RESEARCH

TOPIC BASIC DATA 10 - 20 - 30 RM GROUPS

APPENDIX A

TABULATION SHEET

DATE OF TABULATION MAY, 1957

TABULATED BY DON R. POTTER

	SUBJECT	GROUP	DYNAMIC STRENGTH INITIAL (lbs.)	DYNAMIC STRENGTH FINAL (lbs.)	STATIC STRENGTH INITIAL (lbs.)	STATIC STRENGTH FINAL (lbs.)	HYPERTROPHY INITIAL (gms.)	HYPERTROPHY FINAL (gms.)	DECREMENT INITIAL (lbs.)	DECREMENT FINAL (lbs.)
1		10 RM								
2	D.T.		55	95	242.5	282.5	3311.8	3540	37.5	-15
3	B.T.		65	100	137.5	397.5	4323.7	4644.6	17.5	-62.5
4	P.W.		73	107.5	260	285	2561.1	2613.2	5	-15
5	D.B.		50	100	212.5	287.5	2707.3	2934.2	-2.5	-22.5
6	MEAN		60.75	100.625	213.125	313.125	3225.9	3433	14.375	-28.75
7										
8		20 RM								
9	K.W.		50	87.5	242.5	290	2416.6	2597.5	17.5	50
10	D.M.		58	102.5	142.5	300	1604.9	1601.5	52.5	-12.5
11	J.H.		70	120	259	317.5	4185.5	4193.8	1.5	-52.5
12	J.S.		55	95	209	280	2356	2557.7	39	-57.5
13	MEAN		58.25	101.25	213.25	296.875	2640.750	2732.625	27.625	-18.125
14										
15		30 RM								
16	M.E.		83	115	235	340	2165.3	2255.2	15	-35
17	B.R.		63	80	137.5	227.5	2893.1	3193	17.5	-30
18	C.B.		75	112.5	265	300	2015.9	2364.2	15	- 5
19	H.W.		60	90	210	240	2716.3	3222.9	40	75
20	MEAN		70.25	99.375	211.875	276.875	2447.6	2758.8	21.875	1.25

G-1979

APPENDIX B

TABLE III

ANALYSIS OF VARIANCE RESULTS
OF DYNAMIC STRENGTH: DIFFERENCES BETWEEN GROUPS

SOURCE OF VARIANCE	SS	df	MS	F	CRITICAL F VALUE (5% LEVEL)
Between Groups	423.8	2	211.9	3.8	5.1
Between Subjects	136.8	3	45.6	.8	4.8
Residual	335.0	6	55.8		
Total	895.7	11			

TABLE IV

ANALYSIS OF VARIANCE RESULTS
OF STATIC STRENGTH: DIFFERENCES BETWEEN GROUPS

SOURCE OF VARIANCE	SS	df	MS	F	CRITICAL F VALUE (5% LEVEL)
Between Groups	2453.4	2	1226.7	.4	5.1
Between Subjects	3071.0	3	10263.7	3.7	4.8
Residual	16562.1	6	2760.4		
Total	49806.6	11	4527.9		

TABLE V

ANALYSIS OF VARIANCE RESULTS
OF STRENGTH DECREMENT: DIFFERENCES BETWEEN GROUPS

SOURCE OF VARIANCE	SS	df	MS	F	CRITICAL F VALUE (5% LEVEL)
Between Groups	16792.1	2	8396.1	3.4	5.1
Between Subjects	1585.8	3	528.6	2.1	4.8
Residual	14748.4	6	2458.0		
Total	33126.3	11			

TABLE VI

ANALYSIS OF VARIANCE RESULTS
OF HYPERTROPHY: DIFFERENCES BETWEEN GROUPS

SOURCE OF VARIANCE	SS	df	MS	F	CRITICAL F VALUE (5% LEVEL)
Between Groups	91873.0	2	45936.5	2.5	5.1
Between Subjects	52849.8	3	17616.6	1.0	4.8
Residual	109570.9	6	18261.8		
Total	254293.7	11	23117.6		

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