THE EFFECTS OF SELECTED WEIGHT TRAINING PROGRAMS ON THE DEVELOPMENT OF STRENGTH AND MUSCLE HYPERTROPHY

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John Patrick O'Shea

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THE EFFECTS OF SELECTED WEIGHT TRAINING PROGRAMS ON THE DEVELOPMENT OF STRENGTH AND MUSCLE HYPERTROPHY

By

John Patrick O'Shea

AN ABSTRACT OF A THESIS

Submitted to the College of Education of
Michigan State University of Agriculture
and Applied Science in partial
fulfillment of the require-
ments for the degree of

MASTER OF ARTS

Department of Health, Physical Education, and Recreation

1962

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ABSTRACT

THE EFFECTS OF SELECTED WEIGHT TRAINING PROGRAMS ON THE DEVELOPMENT OF STRENGTH AND MUSCLE HYPERTROPHY

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Statement of the Problem

To determine the effects of selected weight training programs using varied repetitions on the development of strength and muscle hypertrophy.

Methodology

Thirty subjects were chosen at random from beginning weightlifting classes at Michigan State University. Following a two-week conditioning period the subjects were randomly divided into three groups of ten each for the controlled training period. The programs were as follows:

Group A - 3 sets of 9-10 repetitions
Group B - 3 sets of 5- 6 repetitions
Group C - 3 sets of 2- 3 repetitions

Individuals in each group handled maximum weight loads for the number of repetitions each were required to perform.

The experiment consisted of six weeks of training, three sessions per week with each session thirty-five minutes in duration. Four testing periods were utilized at the

beginning, second, fourth, and sixth week of training. On a testing day body weight and thigh measurements were recorded, static and dynamic strength were tested on a back and leg dynamometer and a single maximum effort on the deep-knee-bend, respectively. The data were statistically treated, using analysis of variance. The data also being graphically analyzed and percentages calculated.

Conclusions

Within the limitations of the study the following conclusions were drawn:

1. No significant differences were found between the three systems of training.
2. All training procedures resulted in an improvement of dynamic and static strength.

ACKNOWLEDGMENT

The author wishes to express his sincerest gratitude to Dr. Wayne D. VanHuss for his unfailing interest and kindness in aiding the author during the preparation of this study.

Appreciation is also extended to the subjects who were very cooperative, and to Dr. Philip J. Clark for his assistance in statistical matters.

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CHAPTER I

INTRODUCTION

Among coaches and athletic trainers today a great deal of controversy exists as to the most efficient system of progressive dynamic weight training to follow. All desire a system of training that will produce the most rapid increase in strength and muscle hypertrophy within a limited time period. There is no generally accepted routine of weight training that one can follow. It may be said that the optimum method is yet to be formulated.

Seeking to find the answer to the phenomenon of strength and muscle hypertrophy, a vast amount of experimental work has been done in recent years on animals by physiologists. Some of their findings have made it possible for dynamic weight training exercise to be applied on a scientific basis in physical medicine. In rehabilitation hospitals progressive dynamic weight training is now generally utilized. This has evolved partly by trial and error and partly by imitating the methods weightlifters have used for many years. A great compliment was paid to weightlifters by De Lorme and Watkins[1] who pointed out that "they had supplied a rich heritage of empirical practice which has been

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[1]T. L. DeLorme and A. L. Watkins, "Techniques of Progressive Resistance Exercise," Archives of Physical Medicine, 29:263, May, 1948.

applied to physical medicine.

It is generally thought that the repetitions and loads used on a clinical basis are inadequate for increasing strength and muscle hypertrophy needed by football players, shot putters, discus throwers, swimmers, weightlifters, and other athletes. The objectives of this study are to try and find an efficient result-producing mode of dynamic progressive weight training. A system capable of developing massive muscle hypertrophy or increased strength in the shortest possible time. Such a training program would be an invaluable asset to any athlete as a pre-season conditioning routine and as an aid to correct specific individual weaknesses.

Statement of the Problem

To determine the effects of selected weight training programs using varied repetitions on the development of strength and muscle hypertrophy.

Purpose of the Study

Most coaches and athletic trainers today are conscious of the fact that strength and muscle hypertrophy can be developed through a system of progressive dynamic weight training. Many coaches though refrain from having their athletes supplement their training with weight training because of the lack of a generally accepted and proven program to follow. Coaches and athletes desire a practical program that produces desirable results in a specified limit of time. Most weight training practiced by athletes is performed as a pre-season conditioner where time is limited. During this period of conditioning it is the objective of the athlete to increase his strength and/or muscle hypertrophy to whatever limits it is physically possible.

What system of dynamic weight training should be practiced if the desired results are to be realized? A system in which the individual performs three or four tests of many repetitions (10-12), or medium repetitions (5-6), or minimum repetitions (2-3), with a maximum load for the given number of repetitions being executed. Varying the weight load and the number of repetitions should have an effect on the quality of strength a muscle developed.

Definition of Terms

Repetition: One execution of an exercise or movement.

A set or bout: A series of repetitions with no rest in between.

Program: A series of sets of a particular exercise or exercises separated by rest. Example: An individual performing one push-up is doing one repetition. If he performs two or more in succession he is doing one set. Now, if he were to do one set of five repetitions, then take a one-minute rest, then repeat the exercise for another five repetitions, he would be doing a program of two sets of five repetitions.

Deep-Knee Bend: The barbell is placed on the shoulders at the back of the neck. Keeping the back straight and head back, the exerciser lowers into a full squat and rises. Breathing with the exercise, the exerciser inhales before executing the exercise and exhales near the completion.

Dynamic training: Exercise that allows the muscles to contract through the full range of movement. The load of resistance is moved and mechanical work performed. Strength developed through this type of training is referred to as Dynamic Strength.

Static training: Working the muscles against an immovable load or resistance (static contraction). Muscle and bone joints do not move through the entire range of movement. Strength developed through this type of training is Static Strength.

Muscle hypertrophy: As referred to in this study is an increase in muscle circumference indicated by a tape measure. With the use of the tape measure the increased girth of the extremity at best is only a rough estimate of hypertrophy of a muscle contained therein.

Limitations of the Study

1. Confined to dynamic training only.
2. Limited to men with no previous weight training experience.
3. The study is of relatively short duration.

CHAPTER II

REVIEW OF THE LITERATURE

In reviewing the research literature relating to strength development and muscle hypertrophy, there is general agreement that both can be best developed through the practice of dynamic weight training. However, there is controversy concerning the most efficient method that should be followed. Most weight training programs have an empirical rather than an experimental basis. Coaches and trainers have avoided the use of weight training in their conditioning programs because of poorly defined programs and because they were not certain of the effects.

Through the practice of progressive resistance exercise, De Lorme and his co-workers[1] produced an increase in the circumference and strength of the arms and thighs. To build up power and muscle hypertrophy De Lorme used a system of heavy resistance-low repetition exercise. He described power as the whole potential strength of a muscle used over a short period of time (as in weightlifting) and endurance as the ability to use a muscle against moderate or light resistance for long periods (as in bicycle riding). De Lorme

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[1] T. L. De Lorme, B. G. Ferris, and J. R. Gallagher, "Effects of Progressive Resistance Exercise on Muscle Contraction Time," The Archives of Physical Medicine, 33:86, February, 1953.

recommends a system of heavy resistance-low repetition exercise to build up power and volume in muscle groups, and low resistance-high repetition exercise to develop endurance. The De Lorme technique of training is to start during an exercise session with a light weight for a given number of repetitions and progressively increase the load from one-quarter to one-half to three-quarters and then the total load.

Zinovieff[2] believes that De Lorme's technique is too fatiguing and exhausting and that too great a strain is placed on the muscles. Using a modified form of De Lorme's system, Zinovieff developed what he called the "Oxford technique." The Oxford technique retains the principle of heavy resistance-low repetition, but reverses the procedure of De Lorme by starting with the heaviest weight first and progressively decreasing the load. This system seemed to allow a longer period of exercise with less strain on the subject.

McMorris and Elkins,[3] in a study using both De Lorme's technique and the Oxford technique, found that the Oxford technique produced a 5.5 per cent greater increase in

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[2]A. N. Zinovieff, "Heavy-Resistance Exercise, the Oxford Technique," British Journal of Physical Medicine, 14: 129, June, 1951.

[3]R. O. McMorris and E. C. Elkins, "A Study of Production and Evaluation of Muscular Hypertrophy," Archives of Physical Medicine, 35:420-426, August, 1954.

strength than De Lorme's. They believe that a series of experiments is necessary before it can be concluded that these methods produce consistently different results. In their study, McMorris and Elkins found that strength and muscle hypertrophy developed during a 12-week training period decreased 55 and 56 per cent, respectively, one year later. This may suggest that an individual must train once or twice a week in order to retain the strength and hypertrophy that he has developed during a course of weight training.

MacQueen,[4] in a survey among weightlifters and body builders, found that there is a distinction between the type of exercise used to develop muscular hypertrophy and that used to develop strength. In the hypertrophy program, muscle groups are usually exercised on alternate days in three or four sets of 8-10 repetitions; the weight used being the maximum that can be handled for the given number of repetitions. In the power program the initial weight is never less than the maximum that can be lifted ten times. The power program is essentially one of decreasing the number of repetitions performed with increasing resistance.

In reviewing the literature concerning strength and hypertrophy, it seems that any program of dynamic weight training will increase both in varying degrees. The problem

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[4]I. J. MacQueen, "Recent Advances in the Technique of Progressive Resistance Exercise," British Medical Journal, II:1193-1198, 1954.

is to try and choose the program that is most productive for a particular situation or individual. Capen[5] found that a group using dynamic weight training made greater gains in muscular strength than did a group which did no weight training but practiced track and field events. Capen's program, which consisted of 14 weight training exercises completed in 40 minutes, is mainly designed for building endurance. The power and strength developed by performing 14 exercises in 40 minutes may be limited.

Chui's[6] study consisted of 16 weightlifting exercises performed with high repetitions (8-12). This again was more of an endurance program than power and strength. By the time the exerciser is performing the fourth or fifth exercise his power is pretty well depleted. On this type of program the trainee would seem fatigued himself beyond adequate recovery between workouts.

Kusinitz[7] studied the strength development resulting from a program of five basic exercises. In this study, as in Capen's and Chui's, the experimental group using weights

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[5]Edward K. Capen, "The Effect of Systematic Weight Training on Power Strength and Endurance," Research Quarterly, 21:83-89, May, 1950.

[6]Edward Chui, "The Effect of Systematic Weight Training on Athletic Power," Research Quarterly, 21:188-194, October, 1950.

[7]I. Kusinitz, "The Effects of Progressive Weight Training on Health and Physical Fitness of Adolescent Boys," Research Quarterly, 29:294-301, May, 1958.

dynamically made a greater percentage improvement in strength and anthropometric measurements than the non-weight trained group.

Rasch and Morehouse[8] found the subjects who practiced progressive dynamic weight training showed greater gains in strength and muscle hypertrophy than a non-weight trained group or the group that trained on static resistance. They state the gains made on the program of dynamic training may have resulted from acquisition of skill rather than the exercise program.

Darcus and Salter[9] studied the development of strength through both dynamic and static exercise. Gains were reported in strength resulting from either dynamic or static exercise although dynamic training caused a greater percentage improvement than static training. Differences were found in the pattern of the training curves in dynamic and static exercise. Dynamic exercise generally resulted in immediate and rapid improvement; whereas, static exercise produced no consistent upward trend until the second week of training. Their study also revealed that improvement on maximum static force was developed through dynamic training. However, the

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[8] R. J. Rasch and L. E. Morehouse, "Effect of Static and Dynamic Exercise on Muscular Strength and Hypertrophy," Journal of Applied Physiology, II:29-34, July, 1957.

[9] H. D. Darcus and N. Salter, "The Effects of Repeated Muscular Exertion on Muscle Strength," Journal of Physiology, 129:325-336, August, 1955.

percentage of improvement was much less for maximum dynamic work after training on static exercise.

No review of literature concerning strength development would be complete without including Hoffman. Bob Hoffman is widely known as the "Father of American Weightlifting." Since 1932 he has been U. S. National and Olympic coach. He has spent more than 30 years in the quest of strength. In his latest book, Hoffman[10] claims that the average man can increase his strength 100 per cent in a 20-week period using his system. This system of training is a combination of dynamic and static contraction with weights which allows the trainee to exert maximum force in the various ranges of motions or lifting positions for a period of 8 to 12 seconds. Hoffman claims that one maximum contraction in each position (there are about 12 positions) per training session, three training sessions a week, is all that is necessary to increase strength and muscle hypertrophy. Although he has produced only meager non-scientific evidence to back his claim, this system does merit further investigation and study.

A recent study by Petersen[11] in Denmark found that there was no effect on strength by one static contraction

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[10]Bob Hoffman, Functional Isometric Contractional System (York, Pennsylvania: Bob Hoffman Foundation, 1961).

[11]F. B. Petersen, "Muscle Training by Static Contraction and Eccentric Contraction," Acta Physiologica Scandinavica, 48:406-416, 1960.

per day. Only training by hard dynamic work, not necessarily of maximal intensity, increased the muscle strength. Petersen found that his results were in direct conflict with those reported by Hettinger and Muller[12] who reported that a training program of one static contraction, five days a week, with a tension of two-thirds of the maximum would induce and increase in static strength at 8 per cent per week. Petersen found no great effect on strength if one maximum static contraction per day was performed. He did find that by increasing the number of contractions to ten per day it was possible to show an increase in strength of 13 per cent in 35 days. This is one-fifth of that expected from the results of Hettinger and Muller.

Norbert Schemansky,[13] former World and Olympic weightlifting champion, bases his training entirely on five or six dynamic exercises of three to four sets of two to three repetitions of maximum or near maximum weight load. Schemansky feels that an athlete must practice the full range of movement in order to build strength, speed, timing, and coordination necessary in competitive lifting and other sports.

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[12]T. Hettinger and E. A. Muller, "Muskelleistung and Muskeltraining," Arbeitsphysiologie [redacted], 15:111-126, 1953.

[13]Expressed personal opinion of Norbert Schemansky, personal interview at the Michigan State University Weightlifting Clinic, March 10, 1961.

Mal Whitfield,[14] two-time Olympic 800-meter running champion, followed a progressive weight training program designed to produce maximum strength. One exercise that he devoted much time to was the deep-knee-bend. He practiced this exercise in five sets of three repetitions with heavy weight loads ranging from 255 to 270.

Separate studies by Masley[15] and Wilkins[16] seem to confirm Schemansky's and Whitfield's theory that progressive dynamic training is an effective method for increasing strength, speed, and coordination.

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[14]G. R. Bruce, "Mal Whitfield, Iron-Muscled Running Champion," Strength and Health, December, 1954, p. 8.

[15]J. W. Masley, "Weight Training in Relation to Strength, Speed, and Coordination," Research Quarterly, 24: 308-315, May, 1953.

[16]B. M. Wilkins, "The Effect of Weight Training on Speed of Movement," Research Quarterly, 23:361-369, March, 1952.

CHAPTER III

METHODOLOGY

This study was undertaken to determine the effects of a six-weeks progressive dynamic weight training program, using one exercise, the deep-knee-bend, on the development of strength and muscle hypertrophy. In analyzing the effectiveness of the program, tests and measurements were taken at the beginning of the study and every two weeks thereafter.

Individual tests consisted of maximum single repetition on the deep-knee-bend and the average of two maximum efforts on the back and leg dynamometer. Other measures taken included: body weight (stripped), thigh girths measured with the quadriseps contracted. Measurements of the right thigh were recorded at three different locations: just above the knee (vastus medialis area), middle thigh (vactus lateralis area), and the upper thigh (tensor fascia lata area). Three measurements were taken at each location. The average value was used in subsequent analyses.

Equipment

Regular six-foot steel weightlifting bars and weights were used. Collars on the outside of the bar kept the weight from sliding off. Towels were wrapped around the bar to keep it from digging into the back of the neck, thus making it more comfortable for the subjects. Pipe iron racks, $4\frac{1}{2}$ feet high, supported the bar and weights, saving considerable time and effort.

Subjects

Thirty subjects were randomly selected from beginning weightlifting classes at Michigan State University. The subjects were underclassmen ranging in age from 18 to 23 years. None had previous weight training experience. All subjects lived in University dormitories and, for the most part, ate the same food.

Experimental Procedure

The thirty subjects were given a two-weeks conditioning program to reduce the chance of injury and to familiarize themselves with the deep-knee-bend technique. The techniques involved are: keeping the back straight and head back, lowering into a full squat (parallel or below) and rising, inhaling before executing the exercise and exhaling near the completion.

Following the two-weeks conditioning period, the subjects were randomly divided into three groups of ten each for a controlled training period of six weeks, three training sessions a week, each session lasting 35 minutes.

Training Programs

Group A - 3 sets of 9 to 10 repetitions

Group B - 3 sets of 5 to 6 repetitions

Group C - 3 sets of 2 to 3 repetitions

Individuals in each group handled maximum weight loads for the number of repetitions they were required to perform. Example: In Group A, one subject would be using 150 pounds for his three sets of 9 to 10 repetitions. Another subject of the same group might be using 165 pounds. The weight load for each group was increased five pounds per week. Training days were Monday, Wednesday, and Friday; Monday being the day the weight was increased. Every other Monday was testing and measuring day. On the testing day the subjects were first weighed and the thigh measurement recorded. Next, static strength was tested on the back and leg dynamometer followed by a single maximum effort on the deep-knee-bend to measure dynamic strength. Prior to attempting a maximum effort, the subjects warmed up with lighter weights working up to within 20 or 25 pounds of their previous maximum.

In a regular training day each subject warmed up with light calisthentics before proceeding on to the deep-knee-bend. Each group worked independently of the other. The subjects were under constant observation to insure that correct training procedures were followed. If time permitted each training session ended with form work on one of the three Olympic lifts (press, snatch, clean, and jerk) that the rest of the class was working on at the time.

Methods of Analysis

The results were graphically analyzed and percentages were calculated. The data were also statistically treated using analysis of variance.[1]

[1]C. H. Goulden, Method of Statistical Analysis (New York: John Wiley and Sons, 1952), pp. 63-98.

CHAPTER IV

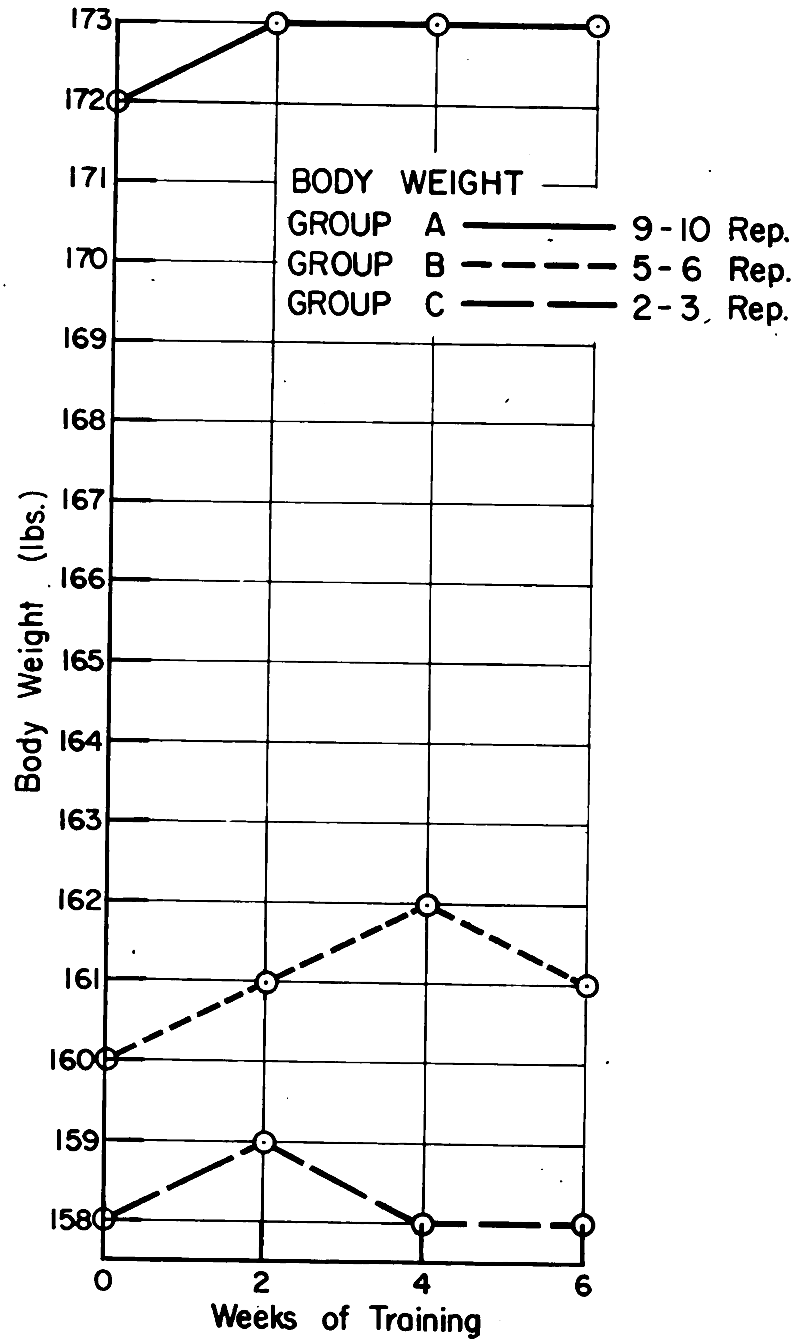
ANALYSIS AND PRESENTATION OF DATA

The effectiveness of the six-weeks deep-knee-bend training program with weights, on the development of strength and muscle hypertrophy, was determined by three measurements: (1) thigh girth, (2) dynamic strength as measured by 1-RM on the deep-knee-bend, and (3) static strength as measured on the dynamometer. The results were graphically analyzed and percentages calculated. The data were also statistically treated using analysis of variance.

Body Weight

The analysis of variance results (see Table I) indicated the weight of the individuals was significantly different in Groups B versus C. In the A versus B and A versus C analysis, the individuals were not significantly different in body weight. This does not imply that the individuals were not different. In placing individuals into groups by random selection there would usually be less variation in group body weights than occurred in this study. In Group A the mean body weight was 172 pounds; Group B, 160 pounds; and Group C, 1958 pounds (see Table II). The test interaction indicates that the training did not significantly alter the body weights of the groups. Groups A and B had

CHART I



GRAPH SHOWING PROGRESS OF GROUP'S BODY WEIGHT mean gains of a pound while Group C did not change.

Girth (Hypertrophy of the Right Thigh)

The analysis of variance results indicates the subjects were significantly different as would be expected. The groups were not significantly different excepting in the upper thigh A versus C analysis., However, in nine analyses one could have occurred by chance alone. All groups increased in girth about an inch (see Table II). However, with the Test interaction indicates this improvement is not significant. The Groups X Test interaction was insignificant as would be expected from the group and test results.

Girth measurement increased on an average of 3 to 6 per cent during the experiment. Charts 2 and 3 reveal that a good percentage of the hypertrophy took place during the first two weeks of the experiment. The notable exception is noted on Chart 3 (middle thigh) where all groups made considerable improvement during the fourth and sixth weeks. Group B showed the greatest mean improvement, 5.2 per cent in girth, Group A 4.2 per cent, and Group C 3.5 per cent.

Static and Dynamic Strength

The groups were significantly different. This could be due to significant differences in their response to training or that since they were not matched at the start of the experiment, they might have been significantly

TABLE I

Analysis of Variance Results

	Body Weight	Girth Right Leg Upper Thigh	Girth Right Leg Middle Thigh	Girth Right Leg 1" above Patella	Static Strength	Maximum Squat
A vs. B						
Groups	2.37	1.89	0.00	0.00	28.60**	8.24*
Test	0.00	0.62	0.72	0.05	40.70**	34.00**
Individuals	1.72	6.10**	3.50**	5.00**	27.30**	14.46**
Groups x Test	0.00	0.16	0.09	0.17	00.00	00.22
A vs. C						
Groups	1.74	7.24*	2.14	0.04	9.80*	39.00**
Test	0.00	1.03	1.64	0.00	16.20**	75.85**
Individuals	1.49	1.89**	10.70**	0.17	6.93**	28.26**
Groups x Test	0.75	0.00	0.02	0.00	1.53	0.95
B vs. C						
Groups	2.21	1.08	1.84	2.20	2.54*	80.98**
Test	0.16	0.56	1.19	0.55	10.70**	55.26**
Individuals	25.15 **	2.15*	5.17**	3.30**	2.50*	9.47**
Groups x Test	0.03	0.00	0.00	0.00	0.80	1.29

**P - less than .001.
*P - less than .01.

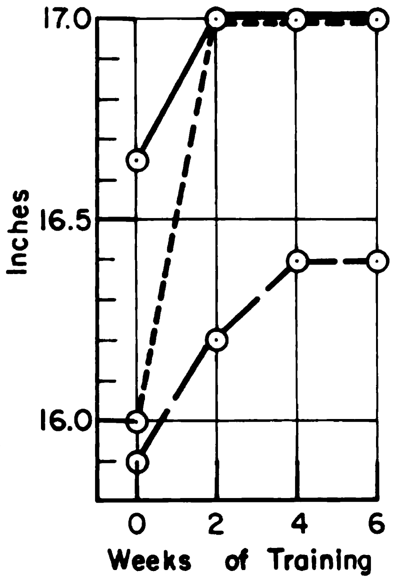
Summary of Changes in Hypertrophy and Strength Over the Experimental Period

TABLE II

Percentage Analysis

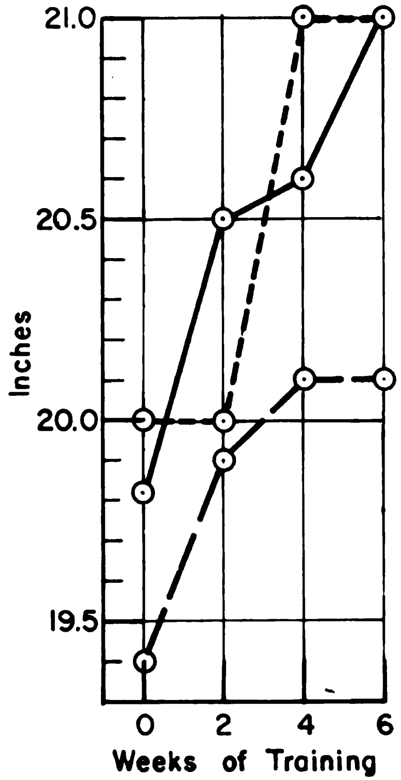
	Group	Initial Test Average	Final Test	Absolute Increase	Total Per cent Increase	Average Per cent Increase Through Testing Periods
Right Leg (vastus medialis)	A	16.6"	17.0"	0.35"	2.1	0.5
	B	16.0	17.0	1.00	6.2	1.5
	C	15.9	16.4	0.50	3.1	0.77
Right Leg (vastus lateralis)	A	19.8	21.0	1.20	5.3	1.4
	B	20.0	21.0	1.00	5.0	1.2
	C	19.4	20.1	0.70	3.6	0.9
Right Leg (Tensor fascia lata)	A	22.7	24.0	1.26	5.3	1.4
	B	22.0	23.0	1.00	4.5	1.1
	C	21.5	22.3	0.80	3.7	0.9
Body Weight	A	172 lbs.	173	1 lb.	--	--
	B	160	161	1	--	--
	C	158	158	0	--	--
Static Strength	A	260	315	55	21.1	5.2
	B	290	335	45	15.5	3.8
	C	280	345	65	23.2	5.8
Dynamic Strength	A	201 lbs.	251	50 lbs.	20.4	5.1
	B	209	265	56 lbs.	26.7	6.6
	C	192	234	42 lbs.	21.8	5.4

CHART 2



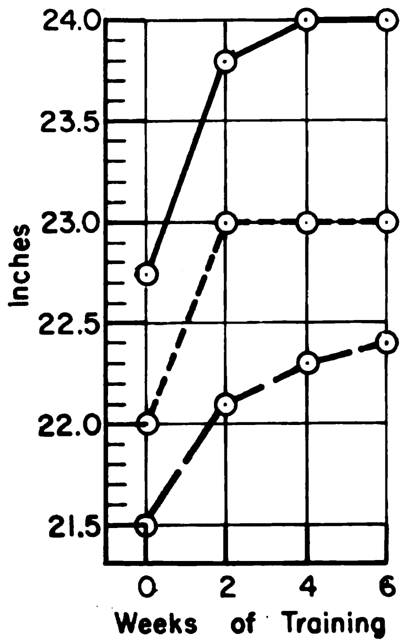
KNEE MEASUREMENT
Vastus Medialis Area

CHART 3



MIDDLE THIGH MEASUREMENT
Vastus Lateralis Area

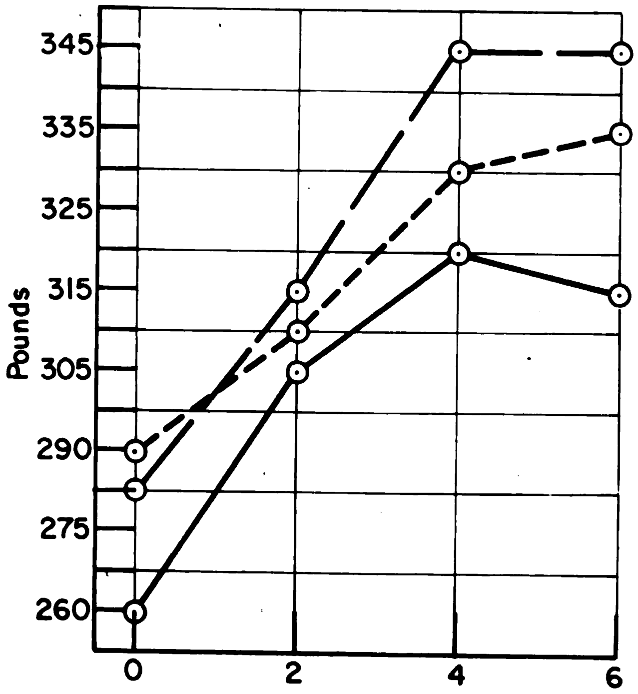
CHART 4



UPPER THIGH MEASUREMENT
Tensor Fascia Lata Area

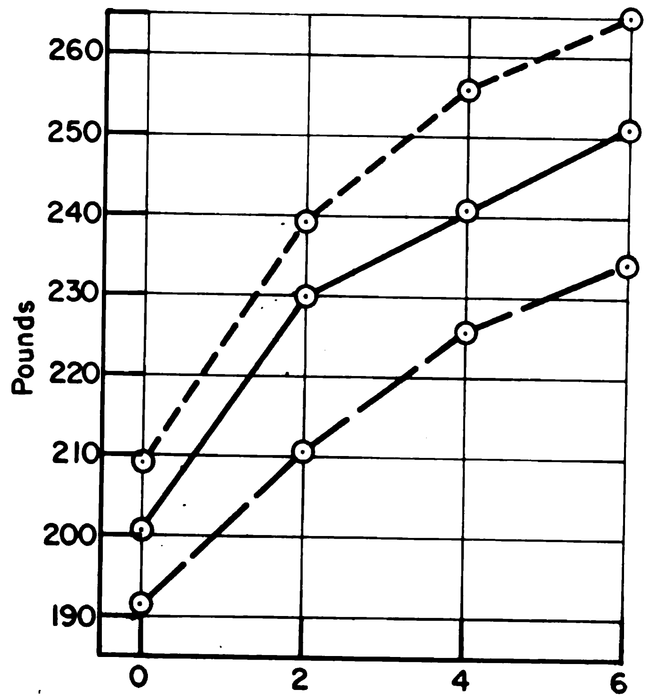
GROUP A ——— 9 - 10 Rep.
GROUP B - - - - 5 - 6 Rep.
GROUP C — — — 2 - 3 Rep.

CHART 5



STATIC STRENGTH

CHART 6



DYNAMIC STRENGTH
(Maximum Squat)

GROUP A ——— 9-10 Rep.
GROUP B - - - - 5-6 Rep.
GROUP C — — 2-3 Rep.

different in strength at the start of the experiment. Since the Group X Test interaction is not significant, no conclusions can be drawn concerning the group differences. The results indicate that the groups responded similarly, that is, all groups improved significantly, but that they did not differ significantly in their response to the various programs. The Test interaction supports this interpretation.

It was the intention in planning the experiment to compare static and dynamic strength results. Darcus' and Salters'[1] work has indicated they would differ. However, in this experiment the statistical results are practically identical. For this reason no comparison has been made; also, for this reason, the data are presented together.

It can be observed in Table II that all groups significantly improved in static and dynamic strength. Group C recorded the greatest mean increase in static strength, 23.2 per cent; Group A, 21.1 per cent; and Group B, 15.5 per cent. For dynamic strength there was a slight inverse relationship with Group B showing a 26.7 per cent gain; Group C, 21.8 per cent; and Group A, 20.4 per cent. Comparing the total mean improvement of all three groups, approximately the same level of achievement was obtained by all. Between the high and low groups there was a separation of only 6.7 per cent for

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

static strength and 6.3 per cent for dynamic strength. Charts 5 and 6 show there was a constant upward movement in static and dynamic strength throughout the testing periods. The only minor exception can be noted for static strength where, on the last testing period, Group C showed no gain and Group A declined slightly.

Discussion

It was thought by the author from empirical experience that Group C, performing 2-3 repetitions, would probably record the greatest improvement. In comparing the average mean increase of the groups, Group C did record the greatest improvement in static strength with a 23.2 per cent increase. However, Group B, while recording an increase of only 15.5 per cent for static strength, led all groups in dynamic strength with a 26.7 per cent increase. There exists an inverse relationship between Groups B and C. Before any definite statement could be made stating which number of repetitions are best for developing strength, a longer study of from 16 to 18 weeks is necessary.

Since, in the analysis of variance results of the present study, the Group X Test interaction was not statistically significant and the total mean improvement of all three groups was approximately the same level, it should make little difference whether an individual trains on three sets of 2 to 3, 5 to 6, or 9 to 10 repetitions.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This experiment was undertaken to determine the effects of a six-weeks progressive weight training program, using one exercise with varying repetitions, the deep-knee-bend, on the development of strength and muscle hypertrophy. Thirty students were chosen by random from beginning weightlifting classes at Michigan State University. Following a two-weeks conditioning period the subjects were divided into three groups of ten each for the controlled training period. The programs were as follows:

Group A - 3 sets of 9 - 10 repetitions
Group B - 3 sets of 5 - 6 repetitions
Group C - 3 sets of 2 - 3 repetitions

Individuals in each group handled maximum weight loads for the number of repetitions each was required to perform. The effectiveness of the program was determined by three measurements: (1) thigh girth, (2) dynamic strength as measured by one RM on the deep-knee-bend, and (3) static strength as measured on the dynamometer. The results were graphically analyzed and percentages calculated. The data were also statistically treated using analysis of variance.

Conclusions

1. No significant differences were found between the three systems of training.

2. All training procedures resulted in the improvement of static and dynamic strength.

Recommendations

1. An experiment of this nature should be carried out for a longer period of time, at least 18 weeks, to determine if all groups would maintain the present rate of progress. It is the author's opinion that a longer experiment would reveal that 2-3 repetitions are best for developing dynamic strength.

2. An experiment of this type should be carried out using both the De Lorme and Oxford techniques.

3. A study should be made to determine the carry-over value of the strength developed through the deep-knee-bend, and improved performance in the three Olympic lifts.

4. A study should be made to determine what percentage of the strength and muscle hypertrophy developed during an experiment of this type is lost over a one-year period.

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APPENDIX

Body Weight

A vs. B

Source of Variance	df	SS	EMS	F
Total	68	70,030		
Groups	1	2,238	2238	2.37
Test	3	13	4	0.00
Individuals	15	24,430	1628	1.72
Groups x Test	3	0	0	0.00
Error	46	43,349	942	

A vs. C

Source of Variance	df	SS	EMS	F
Total	72	66,275		
Groups	1	1,553	1553.00	1.74
Test	3	10	3.33	0.00
Individuals	16	21,197	1324.00	1.49
Groups x Test	3	2,004	668.00	0.75
Error	49	43,511	888.00	

B vs. C

Source of Variance	df	SS	EMS	F
Total	76	28,965		
Groups	1	133	133.00	2.21
Test	3	8	2.60	0.16
Individuals	17	25,661	1509.00	25.15**
Groups x Test	3	6	2.00	0.03
Error	52	3,157	60.00	

**P - less than .001.

Right Leg Measurement
(above the knee, vastus medialis area)

A vs. B

Source of Variance	df	SS	EMS	F
Total	68	262		
Groups	1	0	0.00	0.00
Test	3	3	1.00	0.05
Individuals	15	155	10.00	5.00**
Groups x Test	3	1	0.33	0.16
Error	46	103	2.20	

A vs. C

Source of Variance	df	SS	EMS	F
Total	72	10,278		
Groups	1	7	7.00	0.03
Test	3	2	0.66	0.00
Individuals	16	537	33.00	0.16
Groups x Test	3	0	0.00	0.00
Error	49	9,732	198.00	

B vs. C

Source of Variance	df	SS	EMS	F
Total	76	206		
Groups	1	4	4.00	2.20
Test	3	4	1.00	0.55
Individuals	17	103	6.00	3.30**
Groups x Test	3	0	0.00	0.00
Error	52	95	1.80	

**P - less than .001.

Right Leg Measurement
(middle thigh, vastus laterallis area)

A vs. B

Source of Variance	df	SS	EMS	F
Total	68	370		
Groups	1	0	0.00	0.00
Test	3	8	2.60	0.72
Individuals	15	191	12.70	3.50**
Groups x Test	3	1	0.33	0.09
Error	46	170	3.60	

A vs. C

Source of Variance	df	SS	EMS	F
Total	72	322		
Groups	1	3	3.00	2.14
Test	3	7	2.30	1.64
Individuals	16	242	15.00	10.70**
Groups x Test	3	1	0.33	0.02
Error	49	69	1.40	

B vs. C

Source of Variance	df	SS	EMS	F
Total	76	316		
Groups	1	4	4.00	1.84
Test	3	8	2.60	1.19
Individuals	17	191	11.23	5.17**
Groups x Test	3	0	0.00	0.00
Error	52	113	2.17	

**P - less than .001.

Right Leg Measurement
(upper thigh, tenor fascia lata area)

A vs. B

Source of Variance	df	SS	EMS	F
Total	68	530		
Groups	1	7	7.00	1.89
Test	3	7	2.33	0.62
Individuals	15	341	22.73	6.10**
Groups x Test	3	2	0.66	0.16
Error	46	173	3.70	

A vs. C

Source of Variance	df	SS	EMS	F
Total	72	502		
Groups	1	27	21.00	7.24*
Test	3	9	3.00	1.03
Individuals	16	324	20.00	6.89**
Groups x Test	3	0	0.00	0.00
Error	49	142	2.90	

B vs. C

Source of Variance	df	SS	EMS	F
Total	76	423		
Groups	1	5	5.00	1.08
Test	3	8	2.60	0.56
Individual	17	169	9.90	2.15*
Groups x Test	3	0	0.00	0.00
Error	52	241	4.60	

**P - less than .001.
*P - less than .01.

Static Strength

A vs. B

Source of Variance	df	SS	EMS	F
Total	68	3,968		
Groups	1	186	186.00	18.60**
Test	3	797	265.00	40.70**
Individuals	15	2,680	178.00	27.30
Groups x Test	3	3	0.00	0.00
Error	46	302	6.50	

A vs. C

Source of Variance	df	SS	EMS	F
Total	72	6,732		
Groups	1	294	294.00	9.80*
Test	3	1,458	486.00	16.200**
Individuals	16	3,332	208.00	6.93**
Groups x Test	3	138	46.00	1.53
Error	49	1,510	30.00	

B vs. C

Source of Variance	df	SS	EMS	F
Total	76	5,581		
Groups	1	107	107.00	2.54
Test	3	1,360	453.00	10.70**
Individuals	17	1,816	106.00	2.50*
Groups x Test	3	102	34.00	0.80
Error	52	2,196	42.00	

**P - less than .001.
*P - less than .01.

Maximum Squat

A vs. B

Source of Variance	df	SS	EMS	F
Total	63	102,199		
Groups	1	2,251	2251.00	8.24*
Test	3	27,864	9288.00	34.00**
Individuals	15	59,228	3953.00	14.46**
Groups x Test	3	184	61.33	0.22
Error	46	12,572	273.00	

A vs. C

Source of Variance	df	SS	EMS	F
Total	72	74,797		
Groups	1	3,802	3802.00	39.70**
Test	3	22,076	7358.00	75.85**
Individuals	16	43,875	2742.00	28.26**
Groups x Test	3	276	92.00	0.94
Error	49	4,763	97.00	

B vs. C

Source of Variance	df	SS	EMS	F
Total	76	74,251		
Groups	1	12,958	12958.00	80.98**
Test	3	26,529	8843.00	55.26**
Individuals	17	25,783	1516.00	9.47**
Groups x Test	3	621	207.00	1.29
Error	52	8,360	160.00	

**P - less than .001.
*P - less than .01.