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# Effect of Speed of Muscle Contraction on Strength Improvement

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# EFFECT OF SPEED OF MUSCLE CONTRACTION ON STRENGTH IMPROVEMENT

(TITLE)

BY

Terry Alan Dieckhoff

**THESIS**

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TABLE OF CONTENTS

# LIST OF TABLES

# Chapter 1

## INTRODUCTION

The development of physical fitness should be a concern of everyone. Staying in good physical condition allows an individual to perform his daily tasks and enjoy his leisure time pursuits with enough reserve left to meet any emergencies. A person's physical condition depends on the development of agility, endurance, power, and strength. If a person is going to strive for improved physical fitness, he should consider the development of all these factors.

Maintaining a strong body throughout life will help in preventing musculo-skeletal injuries. With the development of strength, the muscle tissue is protected from sudden stress brought on either by a blow or a heavy strain. The proper development and maintance of strength in opposing muscle groups allows a full range of motion throughout the joints and, therefore, makes them stronger. Strength not only helps in preventing injuries, but also is necessary in overcoming weaknesses due to injuries and in the rehabilitation of injuries (Ryan, 18:314-316). The maintenance of strength as a component in physical fitness is important.

Morehouse and Miller (13:50) defined strength as the ability to exert tension against a resistance. The force required to overcome a resistance can be provided by slow or fast movements. For example, in the bench press, the trainee may allow the weighted bar to come down to his chest slowly and with control. After a complete stop, he then slowly presses upward. The same trainee may perform the same exercise with a very quick movement, down and up, characterized by bouncing the bar off the chest. Which method is the best for the trainee to develop strength? The strength of the contraction is shown to be achieved either by: increasing or decreasing the number of motor units in action or by increasing or decreasing the frequency of discharge in each individual unit (Morehouse and Miller, 13:51).

When comparing slow and fast contractions, results show that a fast contraction has a short burst of impulses from a large number of motor neurons. A slower contraction has a prolonged discharge at a slower frequency. As weight loads are lifted a certain number of times, fresh muscle fibers are called upon to replace the fatigued fibers. According to Morehouse and Miller (13:53), during prolonged effort the nervous system improves the synchronization of motor units. It appears that the additional motor units are called upon during slow, rather then fast contractions. If this concept is valid, then a question arises: Is an exercise performed with a slow contraction likely to develop

more strength than an exercise which is performed with a fast contraction? The following study was initiated to answer this question.

## Statement of the Problem

The purpose of this investigation was to determine what effect the speed of muscle contraction has on the improvement of bench press ability and strength of the anterior chest and posterior upper arm musculature.

## Limitations and Assumptions

One of the basic limitations was that only 65 high school sophomore boys served as subjects. It was also impractical to control the subjects' physical activities outside of class but they were asked not to exercise outside of class for the duration of the study. However, some subjects had certain jobs they had to perform during this time and a few were out for athletics.

In this study, the investigator assumed that all students had the same degree of motivation during the tests and workouts. Also, the subjects were assumed to have the ability to perform the exercise according to the directions given by the investigator. In addition, the investigator assumed that increases in strength in bench press poundage reflect, at least in part, gains in strength of the anterior chest and posterior upper arm musculature.

## Definition of Terms

Bench press. A bench press is a weight training exercise in which one lies flat on his back on a small bench and lowers the weighted barbell to his chest. He then presses the weight upward by extending his forearms.

Isometric contraction. An isometric contraction is a muscle contraction in which the muscle does not shorten during contraction. Tension increases, but no mechanical work is performed.

Isotonic contraction. An isotonic contraction is a muscle contraction in which a muscle shortens against a load or resistance. As a result, the bone moves and the work is performed.

Motor unit. A motor unit is a neuromuscular structure. The unit contains a ventral horn cell, its motor nerve fiber, and the group of muscle fibers supplied by the branches of the nerve fibers.

Muscular endurance. Muscular endurance is the capacity of a muscle to repeat contractions or to continue a sustained contraction against moderate resistance for a period of time.

Muscular strength (dynamic). The capacity of a muscle or group of muscles to exert enough tension to overcome a moveable resistance is referred to as muscular strength (dynamic).

Muscular strength (static). The capacity of a muscle or group of muscles to exert tension against an immoveable resistance is referred to as muscular strength (static).

Repetition. A repetition is a trial where movement occurs in an isotonic cycle. The cycle of the movement includes contraction and relaxation of the muscle.

Set. A set is a continuous and uninterrupted bout of repetitions of one exercise, which may be repeated following a period of rest or another exercise.

## Chapter 2

## REVIEW OF LITERATURE

In this chapter, the investigator reviewed studies relating to the improvement of muscular strength. The summaries of these studies were divided into subject areas. The subject areas were: the principles of muscular strength training, the speed of muscle contraction, isometrics versus isotonics, and resistance versus repetitions.

### Principles of Muscular Strength Training

Perhaps the most basic principle in weight training is the overload principle. In simple terms, the overload principle states that in order to improve in strength the muscle must work under stress. In a study by Hellebrandt and Houtz (10:382), strength training varied with the magnitude of stress, frequency of practice sessions, and duration of the overload. They found that mere repetition of contractions which place no stress on the neuro-muscular system had little effect on the functional capacity of the skeletal muscles.

Berger (5:71) discussed many principles of the muscle contraction in his article. He explained that the force of a muscle contraction is dependent on several factors. These factors are: size of the muscle, its

quality, length of the muscle prior to the time of contraction, number of muscle fibers contracting at once, and muscle insertions around the skeletal joint. Strength occurs by increasing the size of muscle fibers and/or recruiting more motor units during a contraction. This increased recruitment occurs when maximum or near maximum concentric contractions are performed at each repetition in a series of repetitions. It also occurs when stretching a muscle prior to a concentric contraction or rapidly stretching a muscle followed immediately by a concentric contraction.

## Speed of Muscle Contraction

Is speed a factor in strength development? In a study by Chui (6), a comparison was made between the effects of isometrics and dynamic weight training exercises upon strength and speed of movement. The study contrasted slow repetitions with fast repetitions. The results showed that the gains in strength made by use of rapid contraction was not signficantly greater than gains made by slow contraction.

Hanley (9) used the bench press exercise to investigate the factor of speed. He placed 240 males into five experimental groups. Two groups performed fast repetitions. One of these groups exercised with three sets of six repetitions while the other group worked with six sets of one repetition. Two other groups performed slow repetitions.

The slow repetitions were performed with a static pause at the chest. The groups worked at either three sets of six repetitions or six sets of one repetition. The fifth group performed isometric contractions at certain positions through the range of motion. The study found that the group that performed slow contractions of six sets of one repetition had statistically significant gains in the isotonic test over all other groups. The study also showed that the isotonically trained groups surpassed the isometrically trained groups in all of the isometric testing positions with the exception of the first position (at the chest of the subject).

Hill (11) explained in his article that to obtain maximum work from a muscle it is necessary to oppose its contraction at every stage by a force it is just able to overcome. He also stated that at every stage of contraction the force is inversely proportional to the speed of the movement. Slower repetitions allow a muscle to reach its maximum force. Hill also brought out that rapid contraction of the muscle will carry out its movement with greater power with less wasted energy.

Isometrics vs. Isotonics

In another area of strength research, Clark (20) studied and compared isometrics and isotonics. He stated that the amount of tension developed in a muscle is a major

factor in determining strength improvement. He also explained that in isometrics, the contraction restricts the flow of blood to the muscle and thus decreases the amount of oxygen to the muscles. This effect on the oxygen supply restricts the development of muscular endurance when training with isometrics. Even though isometric contractions do not contribute to the endurance of the muscle, they develop strength at those specific points that exercise is performed. In the same article, Clark points out that muscular endurance and retention of strength, is greater after isotonic training than it is after isometric training. This corresponds with the findings of Darcus and Salter (8), who showed no significant difference between isometrics and isotonics. Lorback (12) also observed that isotonic training showed immediate improvement in strength while the gains of isometric training were slow and gradual.

In another study by Salter (19), she investigated whether different repetition rates would effect the strength developed by isometric and isotonic exercises. The isometric and isotonic groups were each divided into two sub-groups, one doing 15 contractions per minute and the other doing two contractions per minute. The results showed that all groups had significant increases in strength, but none proved to be superior to the others.

Rarick and Larsen (16) performed a study in which one group exercised with isometrics daily using a single six

second bout at 2/3 maximum tension. Each day these bouts were performed for longer time periods and at higher levels of tension. The other group exercised daily with isometrics employing repeated bouts at 80 percent maximum tension. Neither group was found to be superior to the other, but they both improved in strength. It was observed that the group training with repetitive bouts retained strength longer after the training had stopped. The investigators concluded that isometrics does improve strength with less time and equipment needed, but improvement is not seen as easily by the trainee.

In another study, Rasch and Morehouse (17) compared isometric and isotonics. They found that the isometric training group improved in strength, but not in the contralateral arm. The isotonic training group showed significant increases in strength in both the exercised arm and the contralateral limb. They also found that when the isotonic and the isometric training groups were tested in an unfamilar position, that the results showed little or no gain in strength in either group. Strength increases have something to do with skill learning.

Resistance vs. Repetitions

In a book by O'Shea (15), strength training is discussed. He explains that increased strength development can be realized by the use of one to three repetitions with

heavy resistance (90 percent of maximum). Eight to twelve repetitions with light resistance is used to develop muscular endurance, but gains in strength can still be realized.

Berger (4) tried to determine the optimum number of repetitions per set that would produce the greatest gain in strength. The study involved 199 male college students three days a week for 12 weeks. The groups were set up by the number of repetitions each individual was to perform: two, four, six, eight, ten, and twelve repetitions. The results showed that the optimum range for developing strength fell between four and eight repetitions. Both four and eight repetitions resulted in higher gains than six repetitions.

In O'Shea's (14) study, three sets of five to six repetitions showed the highest gain in dynamic strength. However, the results were different when the groups were tested by a static test. With a static test, the group that trained with three sets of two to three repetitions showed the highest gain. O'Shea felt that there might not have been any difference between the tests if the study had run longer than six weeks.

Berger (2) also conducted a study dealing with various training loads. The results showed that training three times a week with a training load of 2/3 or more of the maximum load lifted, including one maximum effort per

week, was just as effective for increasing strength as training with a maximum load three times per week. This increase in strength was thought to be largely the result of the one maximum workout each week.

## Summary

The review of the literature appears to indicate that an increase in strength occurs when maximum or near maximum concentric contractions are performed in a series of repetitions. Fast and slow contractions produce increases in strength, but one method has not been proven more effective than the other. Both isometric and isotonic training programs increase strength at the point the muscle is exercised. Isotonics produce strength throughout the whole range exercised. Endurance is gained primarily through low resistance and a high number of repetitions while strength is primarily gained by high resistance and a low number of repetitions.

# Chapter 3

## PROCEDURE

Strength development is important in fitness and rehabilitation. Many investigators have devoted a considerable amount of time to finding out how strength is developed. This study was initiated because very few investigators have researched how strength development is effected by the speed of repetition. The procedure for this study is discussed in the following chapter which contains a description of the subjects, the design of the study, methods of grouping the subjects, and how the subjects were tested.

### Subjects

The subjects were 65 male high school sophomores from two physical education classes which met daily at Barrington Consolidated High School, Barrington, Illinois during the Spring, 1974.

### Design of the Study

The orientation, testing, and training took place in the weight training area located in the wrestling gym of Barrington Consolidated High School. The subjects performed the training during their physical education

classes. Each class period provided for thirty minutes of activity or 150 minutes per week.

The first week of the ten week investigation was devoted to orienting the subjects to the purpose of the experiment and conditioning them to the exercise. At the end of the first week, the subjects were given a pre-training period test in the bench press. The purpose of the pre-test was to determine, by trial and error, the maximum amount of weight each subject could bench press in one repetition. The subjects were given a similar bench press test following the eight weeks (24 sessions) of training. All subjects trained Monday, Wednesday, and Friday and played volleyball on Tuesday and Thursday each week.

## The Bench Press Test

The bench press test was the only test used to determine strength improvement. The test was administered according to the A.A.U. Powerlifting Rules (1). A general warm-up of arm swings and push-ups was used. The subjects were also allowed to work with light poundages in the bench press exercise to further prepare them for the test.

## Test Procedure

The pre and post-training tests were conducted in the same manner. The subject, who was lying on a padded bench, was handed the bar loaded with a specific weight,

which he lowered until it touched his chest. After the bar was held motionless, the subject was given the verbal signal "Press." At this time, he pushed the bar to a fully extended position of the arms. Initially, each subject began with a trial weight he could press with confidence. After each successful trial, ten pounds were added to the bar for the next attempt. When the subject failed at a particular weight, the weight on the bar was reduced by five pounds for a final trial. The investigator recorded the best lift for each subject.

Subject Grouping

The three groups in the study were: Group F (Fast), Group S (Slow), and Group C (Control). After the pre-test was given, the subjects in one of the classes were arranged in rank order from the best bench press to the poorest. From this rank order list, certain subjects were selected in such a way that the mean maximum bench press for Group S nearly equaled the mean maximum bench press for Group C in that particular class. The same procedure was followed in the other class for Group F and the other half of Group C. The groups were selected in this manner to make supervision of the groups easier and to promote competition between the classes.

Group F. Subjects in Group F were instructed to perform the bench press exercise as fast as possible. They

were asked to perform six repetitions with no pause between the repetitions. The subjects used as their guide, tape recorded beats from a metronome (a device used to set musical tempo). The subjects performed three sets of six repetitions with their training weight and had a period of rest between each set, which was approximately three minutes. At first, their training weight was 65 per cent of their pre-training period test maximum. When the subjects were able to perform six repetitions for each of the three sets, they would then add ten pounds to their training weight at the next training session.

Group S. Subjects in Group S were instructed to bring the bar slowly to the chest, hold it there for two seconds, then press the bar to an extended position of the arms. A tape recorder was used to help control the time of the performance by serving as a guide for the subjects. The investigator had pre-recorded on tape the beats of a metronome at 30 counts per minute.

Group C. The subjects in Group C participated in volleyball on Tuesdays and Thursdays with the other groups. On Monday, Wednesday, and Friday the subjects in the group were used as recorders for the other subject's training sessions.

# Chapter 4

## ANALYSIS OF DATA

The study was conducted to find out if, in the performance of the bench press exercise, the speed of repetition had an effect on strength development for 42 high school students. The subjects were divided into three groups and were tested before and after a training program lasting eight weeks.

### Statistical Treatment

A *t* test for correlated and uncorrelated data was applied to determine any statistical difference within the group means and between the group means.

The raw data was punched on I.B.M. computer cards. The *t* test, programmed by DiPietro and Le Duc (7), was used for the analysis. The program was made available through the services of the Eastern Illinois University Data Processing Center.

The .05 level of confidence was selected to denote statistical significant differences between the group and within the group means. The statistical significance of the results between the groups needed a *t* ratio equal to or greater than 2.02 for 40 degrees of freedom. Statistical

significance of the results within the group needed a *t* ratio equal to or greater than 2.08 for 20 degrees of freedom.

## Reliability of Test

Throughout the study, all three groups trained and were controlled under similar conditions. The three groups were selected from two physical education classes which met daily in the morning, one right after the other. Groups F and S both trained for eight weeks, three days each week in the same area of the wrestling gym with the same equipment. The two training groups performed similar warmups before each training session and before the pre-training and post-training tests. All three groups were given similar instructions regarding the test and the same investigator conducted the test for all the groups.

A dynamic test was used instead of a static test. Berger (3) showed that a test which is dynamic in nature will test dynamic strength gains more accurately than a static test. He also found that static tests measure static gains more accurately. Thus, the investigator used a dynamic test.

## Presentation of Findings

The pre-training test ($T_1$) was used to determine group similarity by computing significant differences between the three group means, as shown in Table 1. The

post-training test ($T_2$) was used to determine differences between the groups after the training period, as shown in Table 2. In testing for the significant difference between the two experimental groups, the null hypothesis was used. The null hypothesis stated that speed of repetition would not effect the development of strength.

The findings are presented under the following two headings: Between Group Analysis and Within Group Analysis.

Between Group Analysis. In examination of Table 1, the groups were not found to be significantly different in their pre-training test scores. Even though the groups differed in the means and standard deviations, all three groups were considered similar at the start of the training period.

In examination of Table 2, group F did not show a significant gain in strength over group C, but group S had a significant increase in strength at the .05 level over group C. Further examination shows that neither group F nor group S proved superior to the other at $T_2$.

Within Group Analysis. In examining Table 3, significant gains in strength were evident in each of the three groups. Group C with a $t$ ratio of 2.15 had a significant gain in strength at the .05 level of confidence. Group F and group S both had gains in strength beyond the

Table 1

Summary of Pre-Training Test ($T_1$)
Results Between Groups

| Group | N | $\bar{x}$ | $\sigma$ | t ratio |
|---|---|---|---|---|
| C | 23 | 126.30 | 26.05 | .64 |
| F | 21 | 132.38 | 35.17 | |
| C | 23 | 126.30 | 26.05 | .39 |
| S | 21 | 123.33 | 22.48 | |
| F | 21 | 132.38 | 35.17 | .97 |
| S | 21 | 123.33 | 22.48 | |

Table 2

Summary of Post-Training Test ($T_2$)
Results Between Groups

| Group | N | $\bar{x}$ | $\sigma$ | $t$ ratio |
|---|---|---|---|---|
| C | 23 | 128.40 | 25.22 | 1.201 |
| F | 21 | 140.00 | 38.42 | |
| C | 23 | 128.40 | 25.22 | 2.38* |
| S | 21 | 146.19 | 23.99 | |
| F | 21 | 140.00 | 38.42 | .61 |
| S | 21 | 146.19 | 23.99 | |

*Statistically significant at .05 level of confidence

Table 3

Summary of Strength Gains
Within Each Group

| Group | N | $T_1$ Mean | $T_2$ Mean | $\underline{t}$ ratio |
|---|---|---|---|---|
| C | 23 | 126.30 | 128.04 | 2.15* |
| F | 21 | 132.38 | 140.00 | 4.98** |
| S | 21 | 123.33 | 146.19 | 11.10** |

*Statistically significant at .05 level of confidence

**Statistically significant beyond .001 level of confidence

.001 level of confidence. Group F had a *t* ratio of 4.98, while group S gains provided a *t* ratio of 11.10.

## Discussion of Findings

In the data collected, group's C, F, and S all made significant increases in strength. Group C was assigned to record on cards the training sessions of group's F and S. Group C recorded the weight and the number of repetitions that was lifted for each set. During the non-training days, group C played volleyball with the other training groups. The increase in strength in group C was attributed to eight subjects, each with a gain of five pounds. This increase may be due to several factors. The individuals that experienced the increase in strength may not have been motivated enough at the time of the pre-training test ($T_1$). Other students had activities after school, a few had jobs, and some students were involved in athletics. Any of these factors could also have caused an increase in strength. In addition, their level of motivation at the time of the post-training test ($T_2$) could have brought about this increase. Group C knew what the other subjects were doing during the training sessions, because they were recording the other group's workouts. If group C had not known what the other groups were doing, the results might have been different.

Group F had a gain in strength at the .001 level of confidence, but still did not show a significant gain over group C. Group F's training load was increased after each session that the subject could exercise three sets of six repetitions each. The same procedure was followed with group S.

The investigator observed that subjects in group F reached their near maximum training weight very quickly. This meant that they were training close to a maximum training load each workout in the last half of the eight week training period. Berger (2) found that training three times a week with a training load of 2/3 or more of the maximum load lifted, including one maximum effort per week, was just as effective for increasing strength as training with a maximum load three times per week. Group F might have had different results if they had trained at various percentages of maximum work loads.

Group F appeared stronger with a pre-training ($T_1$) mean of 132.38 lbs., while group S had a pre-training ($T_1$) mean of 123.33 lbs. Even though statistically they were proved similar, group F was stronger, and this might have prevented group F from realizing as large a gain in strength as group S. Also, group F had a large standard deviation score, this would account for group F's smaller $\underline{t}$ ratio score.

Group S trained under similar conditions to group F. Even though group S had a much larger Within Group *t* ratio score than group F, neither group proved to be superior to the other. These results agreed with the work of Chui (6).

## Summary

The findings of the study showed that strength gains can occur (beyond the .001 level of confidence) when fast or slow exercise repetitions are performed. No statistical significant difference was found between strength gains of fast and slow groups.

# Chapter 5

## SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

### Summary

The investigation was designed to study what effect the speed of muscle contraction has on the improvement of bench press ability and strength of the anterior chest and posterior upper arm musculature. In other words, will an exercise that is performed slowly, prove to be superior in strength gains over an exercise that is performed quickly? This study was undertaken to answer this question.

Sixty-five male, sophomore students from Barrington High School (Illinois) served as subjects in the investigation. The subjects were students from two physical education classes, which were divided into three groups. One group was instructed to perform the exercise as fast as possible with no pauses and with a bounce off the chest, if necessary. Another group performed the exercise slowly (one repetition every four seconds). A control group joined the training groups in volleyball on the non-training days.

The subjects trained for eight weeks, three training sessions per week, and were tested prior to and after the training program. The raw scores were punched on I.B.M.

cards and fed through a computer for statistical analysis. The *t* ratios were used to compare the groups and determine the significance of strength gains between and within each group.

## Conclusions

Although strength gains were found for both fast and slow repetition exercise programs, neither method is superior in producing those gains.

## Recommendations

Based on the findings of this study, the following recommendations appear warranted:

1. A similar study should be done with either a longer period of time or with various training loads.
2. A study should be done to see if the speed of repetition has an effect on explosive power.
3. A similar study should be done to see if slow repetitions stimulate greater gains in strength in individuals who are below average in strength compared to individuals who are above average in strength.

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# VITA

## TERRY ALAN DIECKHOFF

The writer was born in Decatur, Illinois on July 29, 1946. He graduated from St. Mary's Catholic Grade School in Paris, Illinois in 1960. He participated in football and track at Paris High School and graduated in 1964.

In the fall of 1964, he entered Eastern Illinois University at Charleston, Illinois. He was a member of the Gymnastic's Team and the Gymnastic's Exhibition Team. In 1968 he captured first place in the still ring competition at the I.I.A.C. Conference Meet and tied for eighth on the rings in the N.A.I.A. Gymnastic's Meet. He also participated in weightlifting intramurals for four years, winning the 132 pound class title each year. He was a member of Phi Epsilon Kappa and the Varsity Club. In May 1969, he received his Bachelor of Science degree in Education.

In the fall of 1969, he started teaching physical education and health education at Barrington High School, Barrington, Illinois. In addition to his teaching duties, he coached freshman football and sophomore gymnastics.

In June 1970, he married the former Patricia Kaye DeVore of Olney, Illinois.

In August 1974, he completed his Master of Science degree in Physical Education and continued teaching and coaching at Barrington High School.