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THE EFFECTS OF A PROGRESSIVE RESISTANCE EXERCISE PROGRAM ON MOVEMENT TIME

By

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B.S., Jamestown College, 1969

Presented in partial fulfillment of
the requirements for the degree of
Master of Science
University of Montana
1971

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Larry A. Hilderman

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Chapter 1

# INTRODUCTION

The force-velocity relationship states that the greater the resistance under which a muscle works the slower will be the movement of that muscle (7). As the resistance to a specific movement increases, the movement time increases. In athletics, specific movements are usually resisted by a load. For example, in golfing the golf swing is resisted by the weight of the golf club. While putting the shot, the resistance is the weight of the shot. Keller (9) reports that there is a positive relationship between the ability to move the body quickly and success in physical activities. Therefore, the individual should work to strengthen the muscle so that it can act more quickly under a load (7).

There is considerable disagreement about the effect of weight training on movement time. It has been shown that gains in strength, whether brought about by isotonic or isometric training, are associated with significant gains in speed (3, 4, 8). The gain in speed has also been demonstrated to result from both strength training involving the same movement as was tested and non-specific training that merely improved the strength of the muscle and avoided training the same movement. On the other hand, Pierson and Rasch (16) reported that a short training program resulted in significant increases in arm strength but was not accompanied by corresponding increases in speed of arm extension.

Meisel (10) investigated the relationship between strength and running speed. He reported that after nine weeks of weight training, increases in strength were not accompanied by increases in running speed. Wilkin (20) reported that a semester of weight training does not decrease movement time more than a semester of beginning golf.

The probable reason for the reported differences in the relationship between movement time and weight training is that strength gains have little effect on movement time for unweighted movements, but strength gains do affect movement time for weighted movements.

This study will attempt to determine the effects of a progressive weight training program on the force-velocity relationship of forearm flexion and quadriceps extension.

## Definition of Terms

The following terms are defined as they were used in this study.

Forearm flexion. Movement at the elbow joint resulting in a decrease in the angle between the anterior aspect of the upper arm and the interior aspect of the lower arm (20).

Force-velocity relationship. The greater the resistance under which a muscle works the slower will be the movement of that muscle (7).

Quadriceps extension. Movement at the knee joint where the angle between the anterior aspects of the lower leg and thigh becomes larger (20).

Repetition. Start and completion of one lift (7).

Six-twelve repetition. The maximum load that can be lifted six times but no more than twelve times.

Set. Six to twelve repetitions.

Movement time. The time taken from the beginning of a muscular movement to the end of that movement (7).

Strength. Maximum load the muscle can lift (7).

Weight training. Program that uses the overload principle. This principle states that in order to develop muscular strength the tension exerted by the muscles must be greater than the tension normally exerted by the muscles (7).

## Chapter 2

## REVIEW OF RELATED LITERATURE

This study is concerned with the effects of a progressive resistance exercise program on the force-velocity relationship. The force-velocity relationship implies that the greater the resistance under which a muscle works the slower will be the movement time of that muscle. As the resistance to a specific movement increases, the slower will be the movement time of that muscle. This can be represented by Figure 1 (7).

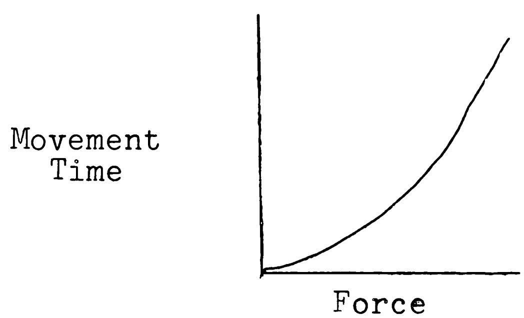


Figure 1

Force-Velocity Relationship

The review will discuss studies that have been made concerning the relationship between strength and movement time, the effects of weight training on resisted movements, and the relationship between weight training and non-resisted movements.

## RELATIONSHIP BETWEEN STRENGTH AND MOVEMENT TIME

Henry, Lotter, and Smith (9) conducted a study to determine the relationship between speed of limb movement and strength of the limb measured in the movement position. They found the correlation to be very low. It usually did not differ significantly from zero.

Smith (18) did a study to determine individual differences in limb strength and limb speed. He concluded that individual differences in speed of limb movement are almost completely unrelated to the measured static strength.

## THE EFFECTS OF WEIGHT TRAINING ON THE SPEED OF RESISTED MOVEMENTS

Colgate (5) carried out a study to determine whether strengthening of arm shoulder muscles functioning antagonistically is accompanied by decrease of speed of movement time of the arm. Fifty-nine male students were selected from Iowa State University. The subjects were divided into three training groups and one control group. The experimental groups were assigned to the adduction flexion group, abduction extension group, and a group that did both types of exercises. The experimental groups exercised with pulley weights for six weeks. The cable tensiometer was used to measure the strength of the isometric contraction of the arm shoulder muscles in the test position. The movements were timed with a standard electric timer. The results reported by Colgate are as follows:

1. A significant increase in the mean strength of the arm shoulder muscle is accompanied by a significant increase in mean speed in the position.

2. There is a positive relationship between initial movement time of the arm and initial movement time against a five-pound resistance.

3. A significant increase in arm shoulder strength in the test position is accompanied by a significant increase in arm speed against a five-pound resistance in the test position.

Chui (3) investigated the effects of isometric and dynamic weight training exercises on strength and speed of execution of single movements. Ninety-six men served as subjects. The experimental groups made up of seventy-two men were enrolled in a beginning weight training course. Group R was the rapid contraction group who exercised at a rapid pace; Group S was the slow contraction group that performed their exercises at a slower rate. The control group included twenty-four men enrolled in other activity courses. The experimental groups lifted weights three days a week for ten weeks. A cable tensiometer was used to measure eight separate strength measures. The measures of movement time with resistance (Resistance I) were taken in the same manner as the measures of movement time without resistance except that a fifty per cent load increase was added to each of the beginning loads. Chui reported the following results:

1. Gains in strength made by the use of the rapid

contraction method were not significantly greater than gains made by the slow contraction method.

2. Gains in strength in performing a movement were accompanied by gains in speed of execution of the same movement measured against resistance of a magnitude equal to those employed in this study.

3. Gains in movement time against no resistance made by the use of the rapid contraction method were not significantly greater than gains made by the slow contraction method.

4. Gains in movement time against resistance made by the use of the rapid contraction method were not significantly greater than gains made by the slow contraction method.

## RELATIONSHIP BETWEEN WEIGHT TRAINING AND NON-RESISTED MOVEMENTS

Chui (2) reported that seventeen out of twenty-two male college students who had engaged in a three-month weight training program showed a mean improvement of .33 seconds in a sixty-yard sprint. Four members of the experimental group showed no significant increases, while the remaining subject was .1 of a second slower after the weight training program. A control group did not show such consistent gains in speed.

In an attempt to determine the effect of weight training on running, Meisel (10) gave 104 subjects a fifty-yard sprint test and a back strength test by using a dynamometer. He divided the subjects into two groups as a result of these tests. Group one trained using a progressive weight training program, while group two attended a sport lecture and did not participate in any organized activity. The experiment extended over a period of eight weeks. Meisel reported that group one showed a loss of speed at the .03 level of confidence, while group two showed no increase in speed.

Barnes (1) used two groups of nine boys to determine running speed for the 100-yard dash. One group had fourteen weeks of physical education with basketball, tumbling, volleyball, and dodge ball. The other group spent equal time in a progressive weight training program. The weight training program consisted of three sets of eight repetitions of half squats, curls, and full knee bends. Both groups ran two 100-yard dashes for time per week with fifteen minutes rest between. In the group having physical education classes, one boy ran slower and seven showed no improvement. All the boys in the weight training program improved. The mean gain of the physical education group was .2 seconds and the mean gain of the weight training group was .7 seconds.

Phillips (15) studied the effects of weight training on sprinting starts. Ten sprinters and hurdlers at the University of Rochester were timed electrically in five starts for fifteen yards. Individuals were assigned to two groups on the basis of their best times. One group did deep knee bends with the forward foot on a platform ten inches above the ground. The other group lay prone with knees flexed at ninety degrees and raised a load in back of the knees while keeping the hips in contact with the ground. Post tests showed that acceleration increased significantly in both groups with the knee-bend group having a greater increase. The exercises were continued throughout the track season and new records were set in the 100-yard and 440-yard dashes and the high hurdles. The 220-yard dash record was tied.

O'Shea (14) studied the effect of weight training on the development of strength and speed required for the 400-meter run. Thirty freshmen were chosen randomly from the University of Oregon. They trained three times a week for eight weeks. Group A trained using four sets of 4-5 repetitions. Group B trained using four sets of 9-10 repetitions. Group C trained using four sets of 14-15 repetitions. There were two time trials administered on consecutive days of both the pre and post test with the fastest time recorded. All three weight training programs used were equally effective in increasing muscular endurance, dynamic strength, and speed in the 400-meter run. All the groups made significant improvement at the .05 level. There were no significant differences between the groups.

Murray and Karpovich (12) also became interested in strength and the movements that concerned the entire body. They designed exercises to be used by a group of basketball players. All of the exercises were concerned with weight training with the exception of the vertical jump. The clean and press, curl, lateral raise, forward raise, squat, pull over, and vertical jump were included in the program. All exercises were done in two sets of ten repetitions over a period of two months. The weight loads and repetitions were gradually increased over the exercise period. The authors concluded that increases in strength were accompanied by increases in running speed for the 100-yard dash.

Haerobedian (8) designed a study to determine whether weight training would increase movement time. Twenty-four subjects were assigned to a weight training class that met every Monday, Wednesday, and Friday for five weeks. Forty-five subjects either served as controls or participated in a volleyball class. All subjects were given pre and post tests of strength and movement time. The movement was the right arm flexion. Haerobedian concluded that weight training brought about a significant increase in speed. The volleyball class had significant speed decrease, and the control group experienced no apparent change in speed. He reported that strength increase appeared to be related to speed; however, correlation data was not reported.

Endries (6) reported that two experimental groups, one training with four-pound weights and the second training with eight-pound weights, exhibited daily improvement in speed of elbow flexion and extension movements. Subjects for this study were forty-five eighth and ninth grade boys. These groups reached a temporary plateau in movement time after the fifth session, but improved again through the last four of the sixteen exercise sessions. Movement time improved 50 per cent for both groups. These increases by the experimental groups were significantly greater than gains in movement time by the control group.

Nelson and Fahreny (13) studied the relationship between maximal strength and speed of elbow flexion. Thirty-one male students were used as subjects. There were fifteen in a weight training program and sixteen in a badminton class. The elbow flexion strength tests, which included two trials twenty seconds apart, were given on two days. The mean of the tests was used. Ten movement time trials, eight seconds apart, were completed on each of three days. The mean was used to represent the movement time score. The authors reported that a moderately high ($p < .001$) correlation existed between strength and movement time.

Clark and Henry (4) also attempted to study the possibility that movement time can be decreased by strengthening the muscles that cause that movement. Two groups of subjects were tested. Group I was the control group, which consisted of thirty-one men who refrained from any type of physical activity. Group II consisted of thirty-one men who were enrolled in a beginning weight training class. Group II met two times a week for thirty-five minutes each time. The girdle muscles were strengthened by weight lifting. The movement that was chosen was the adductive horizontal arm swing. Three tests for strength were used and averaged. Ten weeks later each of the tests were duplicated. The results found by Clark and Henry are as follows:

1. Conditioning exercises of the progressive resistance type that do not directly involve a lateral arm test movement apparently cause increases in mean arm strength in the test position.

2. In the arm movement studied, individual differences in the amount of change in strength have a low but positive correlation with individual changes in maximal movement time.

3. When no changes are involved, there is no consistent correlation between differences in strength and maximal movement time.

Wilkin (19) tested the movement time of the arm action of a group of university students before and after a course in weight training and compared the movement time of a group of experienced weight lifters against a control group. Wilkin used two experimental groups and one control group in this study. Group I had no previous weight lifting prior to the weight lifting course. Group II included members of the weight lifting team from the University of California. The control group consisted of golfers. The apparatus used to test the movement time of the arm was a bicycle crank seven and one-fourth inches in diameter. An electrical counter read at fifteen-second intervals permitted analysis of the subjects' rate of turning the crank. The experimental groups lifted weights for one hour, three days a week, for one semester. The following results were reported by Wilkin:

1. Weight training over an interval of one semester has no slowing effect on speed of arm movements as measured in this study.

2. The experienced or chronic weight lifters were not muscle-bound in the sense that their movement time was impaired. Their speed was as great as that of the other subjects studied.

3. A one-semester weight training program does not increase speed of arm movement more than a semester of beginning golf.

Smith (18) carried out an investigation to determine to what degree, if any, a combined strengthening program of isotonic and isometric exercises would affect the speed of a standardized arm movement. Smith used one experimental group and no control group. The experimental group included twenty-six male subjects who were members of a weight training class. The class met two times a week for thirty minutes. The weight training class continued for twelve weeks. The arm movement speed and arm strength of each subject was measured prior to and following the strength training program. A thirty-five kilogram spring dynamometer was used to measure strength. The arm movement was the free arm swing. Smith concluded that significant increases were recorded in static strength, the free swing, and speed, with most substantial increases in speed occurring during early intervals of the movements.

Zorbas and Karpovich (21) studied the effect of weight lifting on the muscles of the arm of the upper girdle. Six hundred men were used as subjects. They were divided into one experimental and two control groups. The experimental group consisted of three hundred men who had participated in weight lifting for about six months. The control groups each consisted of 150 men. The first control group, which did not have any type of weight training, was from a liberal arts college. The second control group, which also did not have any weight training experience, was from Springfield College. A specially designed machine recording speed of rotary movement of the arm was used. It registered to the nearest one-hundredth of a second the time it took for twenty-four complete rotations of the arm. Each subject had two trials, three minutes apart. The slowest time was used to represent the subjects' speed. The authors concluded that the weight lifters were faster than the non-weight lifters.

Masley, Haerobedian, and Donaldson (11) conducted an investigation to determine whether strength gains via weight lifting were accompanied by an increase in muscular coordination and speed. Freshmen from Pennsylvania State

College were used as subjects. There were two control groups and one experimental group used in this study. The experimental group consisted of subjects who were enrolled in a beginning weight training class. The two control groups consisted of students enrolled in a beginning volleyball class and students required to attend a sports lecture class with no physical activity. Movement time was measured in terms of the time required to complete twenty-four rotary movements of the arm in a frontal plane. The authors concluded that increases in strength from weight training programs are accompanied by decreases in movement time.

Pierson and Rasch (16) investigated the effect of the development of general arm strength on reaction time and speed of arm extension. Twenty-six junior and senior students from the College of Osteopathic Physicians and Surgeons were tested for reaction time and movement time. They trained on a weight training program for four weeks. Each workout consisted of three sets of the following: military press, curls, bench press, and reverse curls. Reaction time and movement time were measured before and after the four-week weight training program. The authors found that an increase in general arm strength did not affect the speed of reaction or movement time of arm extension.

Berger (1) conducted a study to determine the effect of static strength training at various positions and dynamic strength training through full range of motion on strength, movement time, and power. At the beginning and end of the ten-week training program, the subjects were tested for static strength in the bench press at two positions, movement time of the arm extensors, and power measured by throws for distance using a basketball and medicine ball. The ninety-six males were assigned to three experimental groups that trained either isotonically at the extended position in the bench press or isometrically at the flexed or starting position in the bench press, and a control group. All three experimental groups showed significant gains in static strength at both positions of measurement, in speed, and in the two tests of power. The control group did not make any significant gains. No differences were found among the three experimental groups.

## SUMMARY

The review of literature indicates that as the resistance to a movement increases the time of the movement increases. This is illustrated by the force-velocity relationship. The literature also indicates a relationship between strength gains from a weight training program and decreases in movement time for weighted movements. Several studies indicated that improvement in strength caused some increases in movement time for unweighted movements. In general, therefore, the research to date seems to indicate some relationship between strength gains and decreases in movement time for weighted and unweighted movements. This present study attempted to explore the effects of a progressive resistance exercise program on the force-velocity relationship of forearm flexion and quadriceps extension.

# Chapter 3

## PROCEDURES

### SUBJECTS

Twenty male students who were enrolled in a beginning weight training class at the University of Montana served as subjects for this investigation. They were divided into two groups. Group I consisted of ten subjects who had no previous weight training in the preceding six months. Group II consisted of ten subjects who had weight training in the preceding six months. A third group, Group III, served as a control group. This group consisted of seven male volunteers who were enrolled in a volleyball class. They did not participate in any type of weight training.

Table 1 represents the means of the physical characteristics for the subjects used in this study.

Table 1

Mean of the Physical Characteristics of the Subjects

| Groups | Height in Inches | Weight in Pounds | Age in Years |
|---|---|---|---|
| I | 69.1 | 154.8 | 18.1 |
| II | 70.6 | 164.6 | 18.5 |
| III | 71.1 | 164.1 | 18.6 |

## WEIGHT TRAINING PROGRAM USED

The weight training program used by Groups I and II consisted of the following exercises: military press, supine press, curls, reverse curls, leg presses, and heel raises. The weight training program was performed on the Universal Gym Machine. The subjects trained Monday, Wednesday, and Friday of each week for nine weeks.

The exercises were carried out on the corresponding stations on the machine, with a different muscle group being exercised at each station. The subjects moved the resistance six to twelve repetitions for three sets of each exercise. Load was determined by trial and error. A fifteen- to twenty-second interval was allowed for the subjects to move to the next station. This time interval was found to be sufficient for the subjects to move to the next station and to select the appropriate weight. The subjects increased the resistance by ten pounds when the number of repetitions for a specific movement reached twelve.

### Length of Weight Training Program

The program began winter quarter of the 1970-71 academic year. The subjects trained Monday, Wednesday, and Friday of each week for thirty minutes; training continued for nine weeks. The control group played volleyball on Monday, Wednesday, and Friday of each week for thirty minutes.

<u>Equipment Used in Weight Training</u>

The subjects performed their progressive resistance exercise on two Universal Gym Machines. Each machine had nine stations with different exercises performed on each station. The two Universal Gym Machines are identical in structure and operation.

Figure 2

The Universal Gym Machine Used for Weight Training

MEASUREMENT OF STRENGTH

A phasic strength test using weights was used to measure strength of forearm flexion. The subjects extended their right arms to 180 degrees on the inclined rest. Through trial and error they lifted the maximum amount of weight possible for one repetition to determine strength of forearm flexion. To determine maximum strength, increments of one and one-quarter pounds of weight were added. When the subject could no longer lift the resistance one repetition, his maximum strength was recorded. The subjects were given a five-minute rest between each trial. Each subject was given three trials.

The station designed for leg presses on the universal gym was used to measure strength of the quadriceps extension. Each subject sat in the seat designed for the leg press with his knees flexed at a sixty-degree angle. The sixty-degree angle for each subject was determined by the goniometer. The subject lifted the maximum amount of weight possible. When the subject thought he had lifted his maximum resistance, increments of five pounds were added to the load. When the subject could no longer lift the resistance one repetition, his maximum strength for quadriceps extension was determined. The subjects were given five minutes rest between each trial. Three trials were given each subject.

### Equipment Used in Measuring Strength

Weights were used to measure strength of forearm flexion. An inclined rest was used to prohibit the subjects from lifting their shoulders. The station designed for leg extension on the universal gym was used to measure strength of quadriceps extension.

Figure 3

Measurement of Strength of Forearm Flexion

Figure 4

Measurement of Strength of Quadriceps Extension

## MEASUREMENT OF MOVEMENT

The measurement of movement time for forearm flexion was carried out in the following manner. The subject's right arm was extended 180 degrees on the inclined rest. The back of the subject's right hand rested on a starting device. As the movement was begun, the subject's hand came off the starting device starting the timer. The stop mechanism was placed on the top of the subject's right shoulder. As the subject completed the movement, the dumb-bell touched the stop device, stopping the timer. The movements were timed to the nearest one-hundredth of a second.

To measure movement time of quadriceps extension, the subject ascended six stair steps. There was a string across the first step attached to the starting switch of the Dekan Timer. When the subject started his movement, his foot tripped the string, starting the timer. There was a rubber mat switch on the sixth step. As the subject stepped on the rubber mat, the timer was stopped.

### Movements

There were three different movements for forearm flexion. Movement I measured the movement time of the subject's unweighted arm. Movement II measured the movement time when the subject moved a resistance of one-fourth of his maximal pre test strength. Movement III measured the movement time when the subject moved a resistance of

Figure 5

Measurement of Movement Time for Forearm Flexion

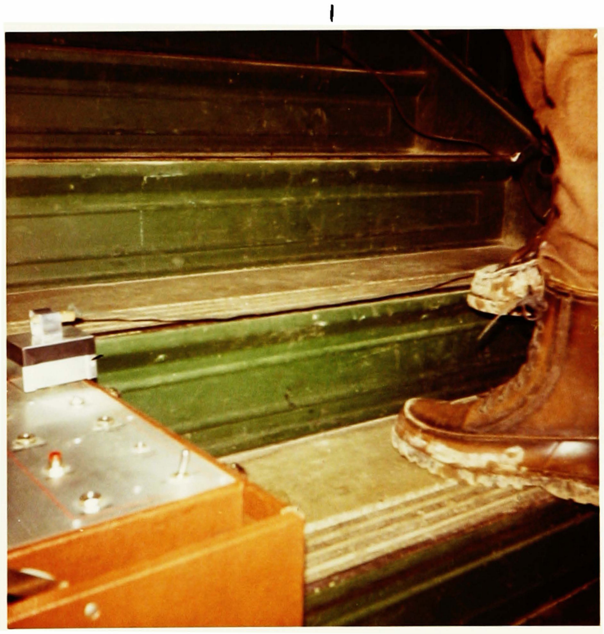

Figure 6

Measurement of Movement Time of Quadriceps Extension

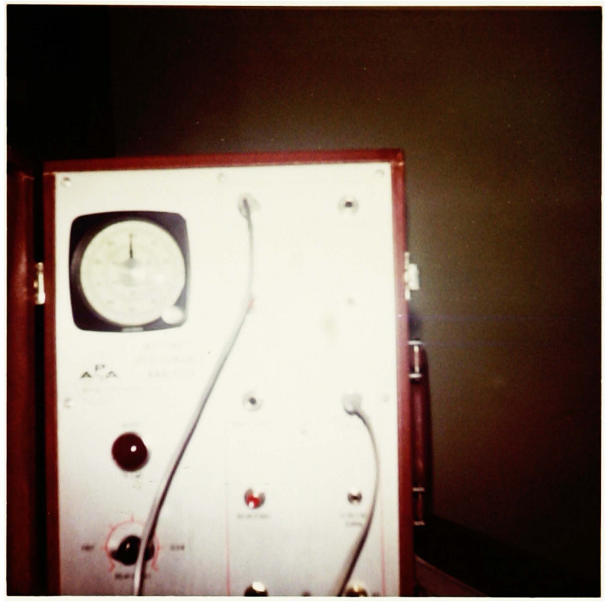

Figure 7

Dekan Timer

one-half of his maximal pre test strength.

There were two different measurements of movement time for quadriceps extension. Movement IV measured the movement time for the unweighted body ascending the six stair steps. Movement V measured the movement time when the subject's body was weighted with twenty pounds. Two ten-pound weights were attached by a belt.

## PRE AND POST TEST OF STRENGTH AND MOVEMENT TIME

The experiment included a pre test at the start of the experiment and a post test at the completion of the experiment. Prior to the pre testing the subjects were given instructions on how to perform the different strength and movement time tests. They also viewed a demonstration of the movements.

The subjects were allowed to practice the various movements three times prior to pre testing and three times prior to post testing. The subjects performed three trials for each of the strength tests and three trials for each of the movement tests. Upon completion of the nine-week training period, the subjects were tested again in precisely the same manner as they had been tested in the pre test.

## STATISTICAL TREATMENT

A "t" test was used to measure the mean difference between pre and post tests for strength of forearm flexion and quadriceps extension. A "t" test was also used to measure the mean difference between pre and post tests for movement time for forearm flexion and quadriceps extension. An analysis of variance was used to measure the differences among the groups. A product moment correlation was used to relate changes in strength to changes in movement time.

## Chapter 4

## ANALYSIS AND DISCUSSION OF RESULTS

This chapter presents an analysis of results obtained in testing two groups of individuals who had trained for nine weeks using a progressive weight training program and a control group that participated in a volleyball class. This study was concerned with determining the effects of weight training on movement time. The writer was interested in ascertaining the effects of weight training on the force-velocity relationship for forearm flexion and quadriceps extension.

### RELIABILITY OF TESTS

The reliabilities of the strength and movement tests are included in Tables 2 and 3. Due to the variable results noted in those tables, the $\overline{X}$ of the three trials was used for each test situation.

### ANALYSIS OF RESULTS

A "t" test, shown in Appendixes C and D, was used to determine significant changes in strength of forearm flexion and quadriceps extension within the groups (Tables 4 and 5). That data revealed highly significant changes in strength of forearm flexion and quadriceps extension.

Table 2

RELIABILITY OF STRENGTH TESTS

| Strength | $\bar{X}$ Difference | "t" | r |
|---|---|---|---|
| Forearm Flexion | | | |
| Trial 1 - Trial 2 | .017 | 1.470 | .64[c] |
| Trial 2 - Trial 3 | .004 | .554 | .53[b] |
| Quadriceps Extension | | | |
| Trial 1 - Trial 2 | .070 | 1.935 | .96[c] |
| Trial 2 - Trial 3 | .150 | 2.358[a] | .98[c] |

[a]Significant at the .05 level.

[b]Significant at the .01 level.

[c]Significant at the .001 level.

Table 3

RELIABILITY OF MOVEMENT TESTS

| Movements | $\overline{X}$ Difference | "t" | r |
|---|---|---|---|
| Movement I | | | |
| Trial 1 - Trial 2 | .005 | 2.525[a] | .38[a] |
| Trial 2 - Trial 3 | .004 | 1.275 | .52[b] |
| Movement II | | | |
| Trial 1 - Trial 2 | .008 | 2.045 | .85[b] |
| Trial 2 - Trial 3 | .006 | 1.325 | .87[b] |
| Movement III | | | |
| Trial 1 - Trial 2 | .001 | .108 | .89[b] |
| Trial 2 - Trial 3 | .003 | .701 | .30 |
| Movement IV | | | |
| Trial 1 - Trial 2 | .020 | 2.487[a] | .90[b] |
| Trial 2 - Trial 3 | .005 | .889 | .41[a] |
| Movement V | | | |
| Trial 1 - Trial 2 | .006 | 1.493 | .96[b] |
| Trial 2 - Trial 3 | .030 | 3.923[a] | .88[b] |

[a]Significant at the .05 level.

[b]Significant at the .001 level.

Table 4

"t" Scores for Groups I, II, and III for Pre and Post Test Changes in Strength of Forearm Flexion

| Group | Pre[b] | Post[b] | Difference[b] | "t" |
|---|---|---|---|---|
| I | 32.75 | 36.60 | 3.90 | 5.8155[a] |
| II | 30.50 | 35.00 | 4.45 | 4.9976[a] |
| III | 28.78 | 31.00 | 2.27 | 8.4139[a] |

[a]Significant at the .001 level.

[b]Values expressed in pounds and decimal fractions.

Table 5

"t" Scores for Groups I, II, and III for Pre and Post Test Changes in Strength of Quadriceps Extension

| Group | Pre[b] | Post[b] | Difference[b] | "t" |
|---|---|---|---|---|
| I | 355.5 | 394 | 39.0 | 4.5512[a] |
| II | 365.6 | 406 | 40.5 | 4.0612[a] |
| III | 307.1 | 331 | 23.9 | 5.2341[a] |

[a]Significant at the .01 level.

[b]Values expressed in pounds and decimal fractions.

An analysis of variance was used to determine whether there was a significant difference among the group means of pre and post test differences for strength of forearm flexion and strength of quadriceps extension (Tables 6 and 7). The analysis of variance technique revealed no differences between the means.

A "t" test, shown in Appendixes E-I, was used to determine whether there was a significant change in movement time within the groups (Tables 8 and 9). The results were as follows:

1. The "t" test showed that for Group I, movement I did not achieve the .05 level of confidence, while movements II and III were significant at the .05 and .001 levels respectively.

2. The "t" test revealed that for Group II, movements I and II were significant at the .05 level of confidence, while movement III did not achieve the .05 level of confidence.

3. The "t" test showed no significant changes for Group III in movements I, II, and III.

4. The "t" test showed that for Groups I and II, movements IV and V were significant at the .01 and .001 levels respectively, while movements IV and V for Group III were not significantly improved.

An analysis of variance procedure was used to determine whether there was a significant difference among group means of the pre and post test differences for each of the

Table 6

Analysis of Variance for Pre and Post Test Differences in Strength of Forearm Flexion

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean Squares | "F" Ratio |
|---|---|---|---|---|
| "Between" Groups | 2 | 21.33 | 10.66 | |
| "Within" Groups | 24 | 103.56 | 4.31 | |
| Total | 26 | | | 2.470 N.S. |

Table 7

Analysis of Variance for Pre and Post Test Differences in Strength of Quadriceps Extension

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean Squares | "F" Ratio |
|---|---|---|---|---|
| "Between" Groups | 2 | 1043 | 521.5 | |
| "Within" Groups | 24 | 36476 | 1519.8 | |
| Total | 26 | | | .343 N.S. |

Table 8

"t" Scores for Groups I, II, and III for Pre and Post Test Changes for Movements I, II, and III

| Group | Movement | Pre | Post | Difference | "t" |
|---|---|---|---|---|---|
| I | I | .190 | .188 | -.001[c] | .3465 |
| I | II | .429 | .382 | -.047 | 2.2043[a] |
| I | III | .582 | .512 | -.07 | 5.1246[b] |
| II | I | .188 | .181 | -.007 | 2.9843[a] |
| II | II | .400 | .369 | -.031 | 2.2481[a] |
| II | III | .578 | .538 | -.041 | 2.1489 |
| III | I | .202 | .204 | .001 | .2532 |
| III | II | .412 | .388 | -.024 | 2.1850 |
| III | III | .585 | .548 | -.037 | 1.7260 |

[a]Significant at the .05 level.

[b]Significant at the .001 level.

[c]Minus sign indicates a decrease in movement time.

Table 9

"t" Scores for Groups I, II, and III for Pre and Post Test Changes for Movements IV and V

| Group | Movement | Pre | Post | Difference | "t" |
|---|---|---|---|---|---|
| I | IV | 1.18 | 1.088 | -.092[c] | 6.2120[b] |
| I | V | 1.15 | 1.07 | -.079 | 4.0244[a] |
| II | IV | 1.14 | 1.02 | -.121 | 4.7996[b] |
| II | V | 1.14 | 1.05 | -.082 | 4.1206[a] |
| III | IV | 1.08 | 1.082 | -.002 | .2256 |
| III | V | 1.08 | 1.09 | 014 | 1.9718 |

[a]Significant at the .01 level.

[b]Significant at the .001 level.

[c]Minus sign indicates a decrease in movement time.

five movements (Tables 10, 11, 12, 13, and 14). The results were as follows:

1. The differences between the means for the three groups for movements I, II, and III were not significant at the .05 level of confidence.

2. The differences between the means for the three groups for movements IV and V were significant at the .05 level of confidence. To determine the location of the differences, the Scheffé test was administered (Tables 15 and 16). The results were as follows:

1. The Scheffé test revealed that for movement IV the differences between the means for Groups I and III and Groups II and III were significant at the .05 level of confidence.

2. The Scheffé test revealed that for movement V the differences between the means for Groups I and III and Groups II and III were significant at the .05 level of confidence.

A Pearson Product Moment Correlation was used to determine the relationship between pre and post test changes in strength and pre and post test changes in movement time for Groups I and II for each of the five movements (Tables 17 and 18). The results were as follows:

1. The correlation coefficient revealed that there was a significant relationship between changes in strength and changes in movement time for movements I and II at the .01 and .001 levels of confidence. However, no significant

Table 10

Analysis of Variance for Movement I

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean of Squares | "F" Ratio |
|---|---|---|---|---|
| "Between" Groups | 2 | .0002122 | .0001061 | |
| "Within" Groups | 24 | .00014852 | .00006188 | |
| Total | 26 | | | 1.7146 N.S. |

Table 11

Analysis of Variance for Movement II

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean of Squares | "F" Ratio |
|---|---|---|---|---|
| "Between" Groups | 2 | .001119 | .00056 | |
| "Within" Groups | 24 | .177849 | .007410 | |
| Total | 26 | | | .075574 N.S. |

Table 12

Analysis of Variance for Movement III

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean of Squares | "F" Ratio |
|---|---|---|---|---|
| "Between" Groups | 2 | .0004 | .0002 | |
| "Within" Groups | 24 | .07956 | .003815 | |
| Total | 26 | | | .049627 N.S. |

Table 13

Analysis of Variance for Movement IV

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean of Squares | "F" Ratio |
|---|---|---|---|---|
| "Between" Groups | 2 | .066 | .033 | |
| "Within" Groups | 24 | .0826 | .00344 | |
| Total | 26 | | | 9.59[a] |

[a]Significant at the .05 level.

Table 14

Analysis of Variance for Movement V

| Source of Variance | Degree of Freedom | Sum of Squares | Mean of Squares | "F" Ratio |
|---|---|---|---|---|
| "Between" Groups | 2 | .04117 | .02058 | |
| "Within" Groups | 24 | .12077 | .00443 | |
| Total | 26 | | | 4.647[a] |

[a]Significant at the .05 level.

Table 15

Movement IV--Scheffé Test

| Difference Between Groups | Mean Difference Between Groups | F |
|---|---|---|
| I and II | .000081 | .0101 |
| I and III | .054200 | 7.133[a] |
| II and III | .0642 | 7.630[a] |

[a]Significant at the .05 level.

Table 16

Movement V--Scheffé Test

| Difference Between Groups | Mean Difference Between Groups | F |
|---|---|---|
| I and II | .003824 | .908 |
| I and III | .065000 | 9.911[a] |
| II and III | .070211 | 10.10[a] |

[a]Significant at the .05 level.

Table 17

Correlation Between Pre and Post Test Changes of Strength to Pre and Post Changes of Movement Time of Movements I, II, III, IV, and V

| Movement | Change in Strength | Change in Movement Time | r |
|---|---|---|---|
| I | 4.15 | -.04[c] | -.82[b] |
| II | 4.15 | -.39 | -.60[a] |
| III | 4.15 | -.55 | -.22 |
| IV | 39.8 | -1.06 | -.10 |
| V | 39.8 | -.81 | -.30 |

[a]Significant at the .01 level.

[b]Significant at the .001 level.

[c]Minus sign indicates a decrease in movement time.

relationship existed between changes in strength and changes in movement time for movements III, IV, and V.

A Pearson Product Moment Correlation was used to determine whether there was a significant relationship between the post test strength and post test movement time for Groups I and II for each of the five movements (Table 18).

Table 18

Correlation Between Post Test of Strength and Post Test of Movement Time for Movements I, II, III, IV, and V

| Movement | Post Test of Strength | Post Test of Movement Time | r |
|---|---|---|---|
| I | 35 | .185 | .01 |
| II | 35 | .375 | .11 |
| III | 35 | .525 | -.01 |
| IV | 400 | 1.05 | .25 |
| V | 400 | 1.07 | .42 |

The correlation coefficient revealed that there were no significant relationships between post test strength and post test movement time for the five movements.

## DISCUSSION OF RESULTS

The results obtained in this study involving a progressive weight training program of nine weeks agree with most of those mentioned in the review of literature. The data in this study clearly demonstrated that all three groups had significant increases in strength of forearm flexion and quadriceps extension. A possible reason that Group III (the control group) had significant increases in strength was that volleyball served as a form of progressive resistance exercise. However, it is more likely that the increments in strength were due, in part, to learning in the test situation (18).

The data revealed that Groups I and II had decreases in movement time for all five movements. These results agree with those of Haerobedian (8), who reported that increases in strength were accompanied by decreases in movement time for right arm flexion. O'Shea (15), studying the effects of weight training in the development of strength and speed required for the 440-yard run, reported that weight training increased muscular strength and speed in the 440-yard dash. Group III did not have any significant decreases in movement time for any of the five movements. Therefore, weight training is more effective than volleyball for creating improvements in movement time. With increases in strength from a progressive weight training program, the movement time in the force-velocity relationship decreases. This is represented by Figures 8 and 9. Movement I decreased .006 seconds, movement II decreased .02 seconds, and movement III decreased .035 seconds. Therefore, with increases in strength from a weight training program, the movement time for forearm flexion decreases, with greater decreases in movement time occurring in the

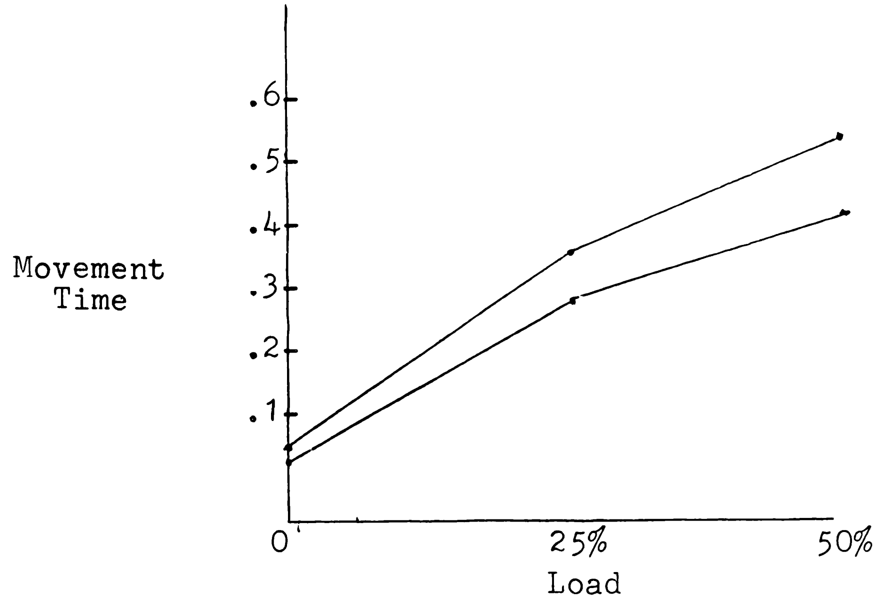


Figure 8

Force-Velocity Relationship for Pre and Post Test for Movements I, II, and III

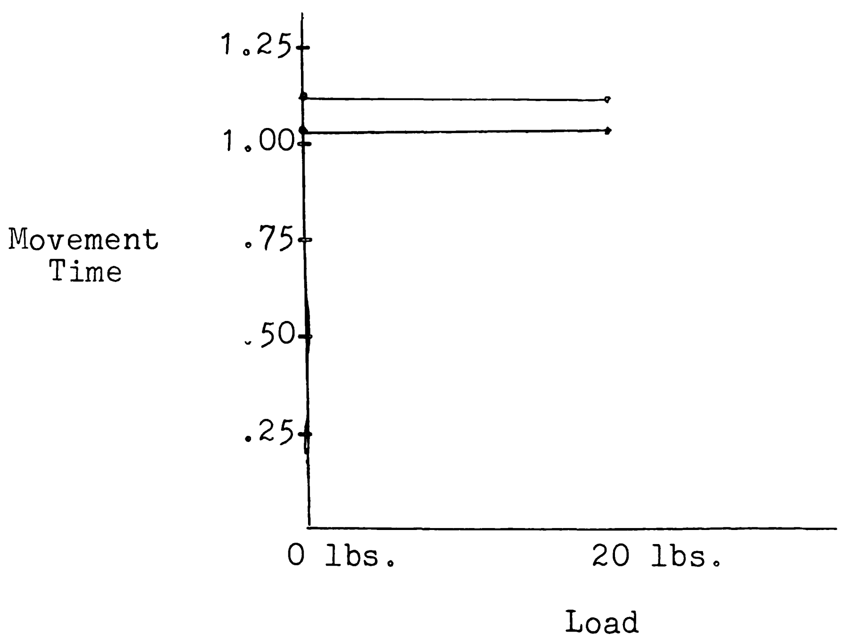


Figure 9

Force-Velocity Relationship for Pre and Post Test for Movements IV and V resisted movements. Movements IV and V had approximately the same decrease in movement time. One reason why Figures 8 and 9 may not agree was that movements I, II, and III were relative loads, i.e., based on a per cent of the subjects' maximum strength, while movements IV and V used absolute loads, or the same resistance for all subjects. It appears that the value of weight training to movement time increases with the size of the relative load, but not when an absolute load is used. The value of strength to the movement of absolute loads seems apparent.

The analysis of variance technique indicated that no significant differences existed between the means of Groups I, II, and III for strength of forearm flexion and quadriceps extension. Therefore, from the data collected it would seem that volleyball was as effective as weight training for developing increases in strength of forearm flexion and quadriceps extension. Golding (7) states that in order to obtain maximum results from a progressive weight training program, a program of at least six months should be used. The data also showed that no significant difference existed among Groups I, II, and III for movements I, II, and III. Contrary to these findings, Haerobedian (8) has shown that a volleyball class had significant increases in speed. It is difficult to explain why such a discrepancy exists between these two studies. The data showed that a significant difference existed among groups for movements IV and V. The weight training groups had greater decreases in movement time than the volleyball group.

In the present study, when correlation coefficients were computed for changes in strength and changes in movement time, the correlations were found to be negative for all movements ($r=-.10$ to $-.82$). However, only movements I and II reached the level of significance. These results are in agreement with those reported by Nelson and Fahrney(14), who indicated a moderately high ($p<.01$) correlation existed between changes in strength and changes in movement time. From the results of this study and others (1, 4, 8, 21), a relationship between changes in strength and changes in movement time does seem to exist.

A correlation coefficient was also computed for the post test strength and post test movement time relationship. The data revealed that for all five movements the relationship was not significant. Four of the five movements had a positive correlation, suggesting that post test strength is not related to post test movement time. This agrees with the findings of Henry, Lotter, and Smith (19), who found that the correlation between strength and movement time was very low and usually did not differ significantly from zero.

The data from this study revealed that increases in strength from a progressive resistance exercise program are accompanied by decreases in movement time. With increases in strength, the movement time of the force-velocity relationship decreases; and as the relative load increases, the value of the increased strength seems to increase.

Chapter 5

# SUMMARY AND CONCLUSION

## SUMMARY

This study was conducted to determine the effect of weight training on the force-velocity relationship of forearm flexion and quadriceps extension. Twenty-seven students enrolled in physical education activity classes at the University of Montana were used as subjects. Each subject was placed in one of two experimental groups according to his prior weight training experience. The control group, consisting of seven volunteers, participated in a volleyball class. The experimental groups trained three days a week for a period of nine weeks.

Each subject was pre tested for strength and movement time. Following the training period, all subjects were retested for strength and movement time. The data was analyzed with "t" tests, analysis of variance, and the Pearson Product Moment Correlation. The "t" test revealed that Groups I, II, and III had significant increases in strength of forearm flexion and quadriceps extension. The "t" test also showed that Group I had significant decreases in movement time for movements II, III, IV, and V; Group II had significant decreases in movement time for movements I, II, IV and V; and Group III did not have significant decreases in movement time for any of the five movements.

The analysis of variance technique indicated that no significant difference existed between the groups for strength of forearm flexion and quadriceps extension or for movement time in movements I, II, and III. However, the analysis of variance technique did reveal significant differences between Groups I and III and Groups II and III for movements IV and V.

The Pearson Product Moment Correlation revealed that a relationship existed between changes of strength and changes of movement time for each of the five movements, with significant correlations for movements I and II. The correlation also revealed that a relationship did not exist between post test strength and post test movement time for all movements.

## CONCLUSIONS

On the basis of the results found in this study, the following conclusions have been made:

1. Groups I, II, and III had significant increases in strength for forearm flexion and quadriceps extension.

2. Groups I and II had significant decreases in movement time.

3. Increases in strength are accompanied by decreases in movement time from a progressive weight training

program.

4. A positive relationship between changes of strength and changes in movement time sometimes resulted from the progressive weight training program.

5. There was no significant relationship between post test scores of strength and post test scores of movement time for any of the five movements.

6. The movement time of the force-velocity relationship decreases with increases of strength from a progressive weight training program.

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APPENDIXES

# APPENDIX A

## SAMPLE DATA COLLECTION SHEET

Name ______________________________________________

PRE TEST DATA

Strength Forearm Flexion

Trial 1. ________

Trial 2. ________

Trial 3. ________

Strength Quadriceps Extension

Trial 1. ________

Trial 2. ________

Trial 3. ________

Movement I

Trial 1. ________

Trial 2. ________

Trial 3. ________

Movement II

Trial 1. ________

Trial 2. ________

Trial 3. ________

Movement III

Trial 1. ________

Trial 2. ________

Trial 3. ________

Movement IV

Trial 1. ________

Trial 2. ________

Trial 3. ________

Movement V

Trial 1. ________

Trial 2. ________

Trial 3. ________

# APPENDIX B

## SAMPLE DATA COLLECTION SHEET

Name ________________________________________________

## POST TEST DATA

Strength Forearm Flexion

Trial 1. ________

Trial 2. ________

Trial 3. ________

Strength Quadriceps Extension

Trial 1. ________

Trial 2. ________

Trial 3. ________

Movement I

Trial 1. ________

Trial 2. ________

Trial 3. ________

Movement II

Trial 1. ________

Trial 2. ________

Trial 3. ________

Movement III

Trial 1. ________

Trial 2. ________

Trial 3. ________

Movement IV

Trial 1. ________

Trial 2. ________

Trial 3. ________

Movement V

Trial 1. ________

Trial 2. ________

Trial 3. ________

# APPENDIX C

Table 19

Pre and Post Test Results of Strength of Forearm Flexion

| Subject | Group I Pre | Group I Post[a] | Subject | Group II Pre | Group II Post[a] | Subject | Group III Pre | Group III Post[a] |
|---|---|---|---|---|---|---|---|---|
| MB | 25.5 | 29.5 | RA | 29.5 | 30.7 | PB | 34.5 | 37.5 |
| JD | 34.5 | -32.0[b] | BL | 29.5 | 34.5 | CF | 29.5 | 32.0 |
| AD | 43.0 | 49.5 | WM | 25.0 | 32.0 | MP | 24.5 | 27.5 |
| SJ | 25.5 | 29.5 | SN | 24.5 | 33.2 | TO | 27.0 | 29.5 |
| CK | 37.5 | 42.0 | GO | 24.5 | 32.0 | DM | 34.5 | 37.0 |
| JL | 25.5 | 32.0 | RB | 39.5 | 39.5 | TA | 34.5 | 35.7 |
| TM | 37.5 | 42.0 | TP | 34.5 | 37.0 | SR | 17.0 | 18.2 |
| JO | 29.5 | 32.0 | KG | 29.5 | 34.5 | | | |
| PS | 34.5 | -32.0 | PF | 29.5 | 34.5 | | | |
| TW | 29.5 | 31.0 | TR | 39.5 | 42.0 | | | |
| Means | 31.7 | 35.6 | | 30.5 | 35.4 | | 28.7 | 31 |
| Difference Between Means | | 3.9 | | | 4.45 | | | 2.22 |

[a]Values expressed in pounds and decimal fraction.

[b]Minus sign (-) means loss of strength.

# APPENDIX D

Table 20

Pre and Post Test Results of Strength of Quadriceps Extension

| Subject | Group I Pre | Group I Post[a] | Subject | Group II Pre | Group II Post[a] | Subject | Group III Pre | Group III Post[a] |
|---|---|---|---|---|---|---|---|---|
| MB | 350 | 420 | RA | 290 | 300 | PB | 310 | -300[b] |
| JD | 390 | 430 | BL | 320 | 340 | CF | 320 | 340 |
| AD | 435 | 440 | WM | 310 | 320 | MP | 290 | 300 |
| SJ | 275 | 300 | SN | 420 | 470 | TO | 300 | 320 |
| CK | 300 | 430 | GO | 255 | 340 | DM | 310 | 340 |
| JL | 305 | -295 | RB | 580 | 610 | TA | 330 | 420 |
| TM | 430 | -410 | TP | 360 | 440 | SR | 290 | 300 |
| JO | 410 | 435 | KG | 360 | 380 | | | |
| PS | 330 | 430 | PF | 340 | 400 | | | |
| TW | 330 | 350 | TR | 420 | 460 | | | |
| Means | 355 | 394 | | 365 | 406 | | 307 | 331 |
| Difference Between Means | | 39 | | | 40 | | | 23 |

[a]Values expressed in pounds and decimal fraction.

[b]Minus sign (-) means loss of strength.

# APPENDIX E

Table 21

Pre-Post Test Results of Movement I

| Subject | Group I Pre | Group I Post[a] | Subject | Group II Pre | Group II Post[a] | Subject | Group III Pre | Group III Post[a] |
|---|---|---|---|---|---|---|---|---|
| MB | .214 | .184 | RA | .218 | .209 | PB | .191 | -.203[b] |
| JD | .210 | -.217 | BL | .175 | -.179 | CF | .185 | -.196 |
| AD | .217 | .207 | WM | .216 | .213 | MP | .198 | .189 |
| SJ | .193 | -.206 | SN | .193 | .191 | TO | .239 | -.272 |
| CK | .178 | .170 | GO | .203 | .189 | DN | .205 | .177 |
| JL | .175 | -.197 | RB | .192 | .187 | TA | .215 | .202 |
| TM | .215 | -.224 | TP | .184 | .171 | SR | .226 | .221 |
| JO | .187 | -.191 | KG | .174 | -.183 | | | |
| PS | .186 | .174 | PF | .183 | .176 | | | |
| TW | .172 | .168 | TR | .187 | .162 | | | |
| Means | .190 | .189 | | .188 | .181 | | .202 | .204 |
| Difference Between Means | | .001 | | | .007 | | | -.002 |

[a]Values expressed in seconds and decimals fractions.

[b]Minus sign (-) means subject became slower.

# APPENDIX F

TABLE 22

Pre and Post Test Results of Movement II

| Subject | Group I Pre | Group I Post[a] | Subject | Group II Pre | Group II Post[a] | Subject | Group III Pre | Group III Post[a] |
|---|---|---|---|---|---|---|---|---|
| MB | .572 | .351 | RA | .218 | .209 | PB | .412 | .393 |
| JD | .442 | -.451[b] | BL | .175 | -.179 | CF | .388 | -.395 |
| SJ | .424 | .406 | WM | .216 | .213 | MP | .483 | .391 |
| CK | .392 | -.407 | SN | .193 | .191 | TO | .413 | .385 |
| JL | .378 | .331 | GO | .203 | .189 | DM | .428 | .421 |
| TM | .390 | .367 | RB | .192 | .187 | TA | .431 | .417 |
| JO | .409 | -.419 | TP | .184 | .171 | SR | .367 | .348 |
| PS | .464 | .369 | KG | .174 | -.183 | | | |
| TW | .454 | .384 | PF | .183 | .176 | | | |
| AD | .409 | .385 | TR | .187 | .162 | | | |
| Means | .429 | .383 | | .400 | .369 | | .412 | .388 |
| Difference Between Means | | .047 | | | .031 | | | .024 |

[a]Values expressed in seconds and decimal fractions

[b]Minus sign (-) means subject became slower.

## APPENDIX G

Table 23

Pre and Post Test Results of Movement III

| Subject | Group I | | Subject | Group II | | Subject | Group III | |
|---|---|---|---|---|---|---|---|---|
| | Pre | Post[a] | | Pre | Post[a] | | Pre | Post[a] |
| MB | .509 | .468 | RA | .840 | .784 | PB | .665 | .523 |
| JD | .742 | .631 | BL | .454 | -.527[b] | CF | .512 | -.517 |
| AD | .598 | .511 | WM | .650 | .565 | NP | .529 | .474 |
| SJ | .475 | -.506 | SN | .508 | .432 | TO | .538 | -.543 |
| CK | .589 | .485 | GO | .517 | .494 | DM | .713 | .699 |
| JL | .508 | .429 | RB | .679 | .529 | TA | .625 | .612 |
| TM | .586 | .519 | TP | .466 | .504 | SR | .552 | .536 |
| JO | .538 | .510 | KG | .538 | -.545 | | | |
| PS | .681 | .541 | PF | .489 | -.565 | | | |
| TW | .652 | .566 | TR | .690 | .486 | | | |
| Means | .582 | .512 | | .578 | .538 | | .585 | .548 |
| Difference Between Means | | .070 | | | .040 | | | .037 |

[a]Values expressed in seconds and decimal fractions.

[b]Minus sign (-) means subjects became slower.

# APPENDIX H

Table 24

Pre and Post Test Results of Movement IV

| Subject | Group I Pre | Group I Post[a] | Subject | Group II Pre | Group II Post[a] | Subject | Group III Pre | Group III Post[a] |
|---|---|---|---|---|---|---|---|---|
| MB | 1.09 | .99 | RA | 1.31 | 1.15 | PB | 1.15 | 1.07 |
| JD | 1.14 | 1.11 | BL | .99 | .93 | CF | .96 | .95 |
| AD | 1.30 | 1.19 | WM | 1.29 | 1.08 | MP | 1.07 | -1.15[b] |
| SJ | 1.12 | 1.04 | SN | 1.15 | 1.06 | TO | 1.06 | 1.05 |
| CK | 1.03 | .95 | GO | 1.23 | .99 | DM | 1.12 | 1.10 |
| JL | 1.16 | .99 | RB | 1.14 | -1.17 | TA | 1.11 | 1.11 |
| PS | 1.49 | 1.32 | TD | 1.23 | 1.00 | SR | 1.08 | 1.08 |
| TW | 1.08 | .99 | KG | 1.08 | .94 | | | |
| TM | 1.22 | -1.27 | PF | 1.06 | 1.00 | | | |
| JO | 1.17 | 1.03 | TR | 1.01 | .96 | | | |
| Means | 1.18 | 1.08 | | 1.14 | 1.02 | | 1.08 | 1.08 |
| Difference Between Means | | .10 | | | .12 | | | .00 |

[a]Values expressed in seconds and decimal fraction.

[b]Minus sign (-) means subject became slower.

# APPENDIX I

Table 25

Pre and Post Test Results of Movement V

| Subject | Group I Pre | Group I Post[a] | Subject | Group II Pre | Group II Post[a] | Subject | Group III Pre | Group III Post[a] |
|---|---|---|---|---|---|---|---|---|
| MB | 1.15 | 1.05 | RA | 1.30 | 1.17 | PB | 1.08 | -1.12 |
| JD | 1.07 | 1.02 | BL | .99 | .98 | CF | 1.05 | -1.11 |
| AD | 1.22 | 1.10 | WM | 1.23 | 1.10 | MP | 1.14 | 1.12 |
| SJ | 1.14 | -1.19 | SN | 1.12 | 1.10 | TO | 1.06 | 1.02 |
| CK | .98 | -.99 | GO | 1.24 | 1.04 | DM | 1.13 | -1.16 |
| JL | 1.18 | 1.01 | RB | 1.11 | -1.20 | TA | 1.08 | -1.11 |
| TM | 1.43 | 1.22 | TP | 1.12 | .96 | SR | 1.04 | 1.04 |
| JO | 1.08 | .98 | KG | 1.12 | .99 | | | |
| PS | 1.21 | 1.16 | PF | 1.05 | 1.02 | | | |
| TW | 1.12 | 1.07 | TR | 1.12 | 1.02 | | | |
| Means | 1.15 | 1.07 | | 1.14 | 1.05 | | 1.08 | 1.09 |
| Difference Between Means | | .08 | | | .09 | | | -.01 |

[a]Values expressed in seconds and decimal fractions.

[b]Minus sign (-) means subject became slower.

# APPENDIX J

## STATISTICAL FORMULAS USED

The Raw Score, or Machine Formula, for computing the Pearson Product Moment Correlation r from Raw Scores.

$$r = \frac{N\Sigma XY - (\Sigma X)\ (\Sigma Y)}{(N\Sigma X^2 - (\Sigma X)^2\ (N\Sigma Y^2 - (\Sigma Y)^2}$$

Testing the Significance of the Difference Between Two Means.

$$t = \frac{\overline{D}}{S_{\overline{D}}}$$

Where

$$D = \overline{X}_1 - \overline{X}_2$$

$$\Sigma d^2 = \Sigma D^2 - \frac{(\Sigma D)}{N}$$

$$S_D = \sqrt{\frac{\Sigma d^2}{N}}$$

$$S_{\overline{D}} = \frac{S_D}{\sqrt{N - 1}}$$

Analysis of Variance Technique.

$$F = \frac{\text{Mean Square for "between" groups}}{\text{Mean Square for "within" groups}}$$

where

$$\text{Between Square} = \Sigma X_b{}^2 = \frac{(\Sigma X)^2}{N} - \frac{(\Sigma X_T)^2}{N}$$

$$\text{Within Squares} = \Sigma X_W{}^2 = X_1^2 - \frac{(\Sigma X_1)^2}{N_1} + \ldots X_N^2 - \frac{(\Sigma X_N)^2}{N_n}$$

Scheffe Test.

$$\frac{(\overline{X}_2 - \overline{X})}{\frac{Sw^2 \; (N_1 + N_2)}{N_1 N_2}}$$

# APPENDIX K

Table 26

Physical Characteristics of the Subjects

| Subject | Height in Inches | Weight in Pounds | Age in Years |
|---|---|---|---|
| Group I | | | |
| MB | 70 | 170 | 18 |
| JD | 69 | 170 | 18 |
| AD | 72 | 138 | 18 |
| SJ | 68 | 160 | 18 |
| CK | 70 | 155 | 18 |
| JL | 71 | 155 | 19 |
| TM | 69 | 140 | 18 |
| TW | 64 | 135 | 19 |
| JO | 67 | 145 | 20 |
| PS | 71 | 180 | 18 |
| Means I | 69.1 | 154.8 | 18.1 |
| Group II | | | |
| RA | 68 | 146 | 18 |
| BL | 70 | 155 | 18 |
| WM | 72 | 195 | 19 |
| SN | 72 | 180 | 18 |
| GO | 75 | 190 | 19 |
| RB | 67 | 165 | 19 |
| TP | 73 | 170 | 18 |
| KG | 67 | 135 | 18 |
| PF | 70 | 145 | 19 |
| TR | 72 | 165 | 19 |
| Means II | 70.6 | 164.6 | 18.5 |

Table 26 (continued)

| Subject | Height in Inches | Weight in Pounds | Age in Years |
|---|---|---|---|
| Group III | | | |
| PB | 67 | 150 | 19 |
| CF | 74 | 215 | 19 |
| MD | 69 | 162 | 18 |
| TO | 70 | 151 | 19 |
| DM | 74 | 160 | 19 |
| TA | 70 | 151 | 18 |
| SR | 74 | 160 | 18 |
| Means III | 71.1 | 164.1 | 18.6 |
| Means | 70.2 | 161.1 | 18.4 |