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RELATIONSHIP OF PHASIC AND STATIC
STRENGTH AND ENDURANCE

By

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B.S.E. Kansas State Teachers College
of Emporia, 1964

Presented in partial fulfillment of the requirements
for the degree of

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UNIVERSITY OF MONTANA

1965

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R.M.

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CHAPTER I

THE PROBLEM AND DEFINITIONS OF TERMS USED

I. INTRODUCTION

A considerable amount of research has been completed on the effects of phasic and static exercises on strength development. Mitchem (22) pointed out the need for further research in phasic and static strength and endurance.

Muscular strength is measured by two different kinds of tests. A phasic strength test measures the amount of contraction force a muscle can attain by shortening its length. A static strength test measures the amount of contraction force a muscle can attain without appreciably shortening the length of the muscle.

The use of a static strength test as the criterion to determine strength changes resulting from phasic muscle training assumes that an increase in one guarantees a proportionate increase in the other. This is indicated in the following studies by the use of static strength tests to measure changes due to both phasic and static training. Salter (27), Sullivan (28), Mathews and Kruse (21), and Rasch and Morehouse (26) compared changes in strength due to phasic and static training by means of a static strength test. The assumption that an increase in phasic strength guarantees a proportionate increase in static strength needs more consideration.

Muscular endurance is repeatedly acknowledged as one of the most important factors determining success or failure in athletic contests. There is evidence that endurance is dependent upon adequate muscle strength. Morehouse (23) points out that endurance may be ameliorated by increasing muscular strength and improving physical conditioning. He also states that an athlete with abundant endurance can sustain strenuous work for long periods of time.

By studying the relationship of phasic and static muscular strength and phasic and static muscular endurance, an increased understanding of strength and endurance are procured. Strength and endurance are an integral part of fitness. By understanding the relationships between phasic and static muscular strength and phasic and static muscular endurance, fitness may be accomplished with greater economy.

II. THE PROBLEM

Statement of the problem. It was the purpose of this study (1) to investigate the validity of employing a phasic strength test to measure static strength improvement, and the validity of employing a static strength test to measure phasic strength improvement; (2) to determine whether a phasic strength measurement is an indication of phasic endurance; (3) to determine whether a static strength measurement is an indication of static endurance; and (4) to determine whether phasic

endurance and static endurance are related.

Importance of the study. A number of studies have been conducted in which phasic and static training programs have been paralleled. In evaluating these training programs only a static muscular strength test is applied to both types of strength. This study, will determine whether phasic and static muscular strength are sufficiently related to justify the use of only one strength test.

A number of studies have related strength improvement to endurance improvement after a training period. After a review of the literature it was established that no study had been conducted which affiliated static and phasic strength to static and phasic muscular endurance.

Cureton (10) refers to muscular endurance as being either phasic muscular endurance or static muscular endurance. From past investigation, most researchers agreed, strength is related to endurance. This was also established by Clarke (3), Tuttle, Janney and Salzano (29), Elbel (14), and Howell, Kimato, and Morford (19). This study was designed to find if there was any relationship between phasic and static endurance and/or maximum phasic and static strength and endurance. With the increased emphasizes on phasic and static training for strength development, it was felt to be of merit to know which (phasic or static endurance) was related to strength.

III. BASIC ASSUMPTIONS

The following assumptions were basic to this study.

1. Phasic and static muscular strength and phasic and static muscular endurance can be measured reliably by those methods described in Chapter III.
2. The elbow flexors are a reliable muscle group for measurement of phasic and static strength and phasic and static muscular endurance (8).

IV. LIMITATIONS OF THE STUDY

The following limitations related to the number of subjects and the muscle group tested.

1. The study was limited to twenty subjects attending the University of Montana. All subjects were male and between the ages of eighteen and twenty-seven.
2. The study was limited to the right elbow flexor muscle group.

V. DEFINITIONS

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

Elbow flexion. Flexion at the elbow when the forearm is moved in a direction that diminishes the anterior angle at the elbow.

Phasic muscular strength. The amount of contraction force the elbow flexors can attain by shortening the length of the muscles in a single contraction.

Static muscular strength. The amount of contraction force the elbow flexors can attain without appreciably shortening the length of the muscle in a single contraction.

Phasic muscular endurance. The number of contractions of the elbow flexors at a rate of thirty contractions per minute, with a load of three-eighths of the maximum phasic strength.

Static muscular endurance. The amount of time the subject could exert sufficient force by sustained contraction of the elbow flexors to hold the tensiometer indicator at three-eighths of the maximum static strength.

CHAPTER II

SURVEY OF RELATED LITERATURE

A voluminous quantity of literature has been written in the last fifteen years on strength and endurance. Since the published study by Hettinger and Müller, static and phasic muscular strength have received increased attention. A brief summary of those studies pertinent to the relationship of phasic and static strength and phasic and static muscular endurance ensues.

I. PHASIC AND STATIC STRENGTH RELATIONSHIP

Little interest was displayed in static weight training until 1953 when the findings of Hettinger and Müller (18) were disclosed. These researchers endeavored to evaluate the worth of static contraction exercise in which the intensity and duration of the exercises were measured to analyze their effect on muscular strength and size. Over an eighteen month period, nine subjects trained through the performance of pulling and holding predetermined amounts of tension against a dynamometer. Increases in muscular strength were more rapid with increasing intensity of training loads up to two-thirds of the maximal strength. One daily exercise bout of static exercises for six seconds at two-thirds maximum resistance was found to be as effective as longer durations of exercise. Hettinger and Müller resolved that daily static exercise

used less time and energy and produced equivalent muscular strength as longer methods.

Berger (1) studied the changes in phasic strength produced by static training and the changes in static strength produced by phasic training. Two groups of subjects trained for twelve weeks. Training statically increased static strength significantly more than training phasically and, conversely, training phasically increased phasic strength significantly more than training statically. An improvement in static strength did not result in a corresponding improvement in phasic strength. Also, an improvement in phasic strength did not result in a corresponding improvement in static strength. This was indicated by the coefficient of correlation between the increment in static strength and the increment in phasic strength from initial to final testing. This was an indication that a phasic strength test should be used to determine strength changes due to phasic training, and a static test should be used to measure strength changes due to static training.

Berger (1) noted that Richards tested 187 subjects for maximum phasic and static strength of the quadriceps femoris muscle group and found a correlation of 0.67 between the two.

The effectiveness of static exercises as opposed to phasic exercises upon the elbow flexor muscles was investigated by Mathews and Kruse (21). One hundred and twenty male

subjects from Springfield College were divided into two weight training groups. Group "A" engaged in phasic resistance exercises. Both groups were further subdivided into four more groups each, totaling eight groups in all. The four groups of group "A", although using the same methods of phasic exercises, trained two, three, four, and five days per week respectively. The four groups of group "B" followed a similar experimental design utilizing static exercises. The members of group "A" trained by means of the Kelso-Hellebrandt ergometer whereas the members of group "B" utilized the Clarke Cable Tension Strength Test which was employed to measure strength gains for both groups. The researchers concluded, as did Hettinger and Müller earlier, that static resistance exercises caused a greater magnitude in muscular strength than was caused by phasic exercises. It was also found that the five-day week exercise program was most beneficial in terms of strength gained.

Rasch (25) studied the relationship between the tension which could be exerted by trained subjects in a single maximum static elbow contraction and the maximum weight which could be moved in a single phasic elbow flexion. Twenty-four male students were trained with progressive resistance unilateral curls and presses for a period of six weeks. At the end of the training period, the amount of tension which could be recorded in a single maximum static contraction,

as recorded on a strain gauge, and the amount of weight which could be handled in a single maximum dumbbell curl were ascertained. It was found that the subjects could exert a mean static tension of 43.2 pounds, with a standard deviation of 3.4 pounds, and a mean maximum phasic contraction of 41.8 pounds, with a standard deviation of 6.9 pounds. The difference of 1.4 pounds between the two means was of no statistical significance. So far as trained male subjects were concerned, there appeared to be no great difference between the amount of tension which could be recorded in a single maximum static elbow contraction and the amount of weight which may be handled in a single maximum phasic elbow flexion.

II. STRENGTH-ENDURANCE RELATIONSHIPS

Clarke (3) states that:

Muscular strength and muscular endurance are not the same, although they are related. Individuals with greatest muscular strength have greatest absolute endurance; however, stronger muscles tend to maintain a smaller proportion of maximum strength than do weaker muscles.

Also Clarke (5) has stated:

The effects of isotonic exercise favor the improvement of muscular endurance and the retention of muscular strength following cessation of exercise. Static contractions restrict blood circulation to a greater extent than do phasic contractions. For static work the amount of oxygen, oxygen debt, and total oxygen requirement increase linearly in pro-

portion to the size of the load; this constriction of circulation with attendant effects on the oxygen supply to the muscles logically restricts the development of muscular endurance when training with static exercises.

Sullivan (28) studied the effects of static and phasic exercise of the quadriceps extensor femoris on strength and endurance. Eighty-one subjects were divided into three groups, one being a control group, and were trained for six weeks. The phasic exercise group exercised twice weekly by lifting a weight, from ninety degrees of knee joint flexion to 180 degrees of knee joint extension. The static exercise was performed with the knee joint at a 165 degree angle and consisted of two six-second maximal contractions of the quadriceps. In the pre-and-post-test, strength and endurance of the right quadriceps were taken. Static and phasic exercise groups were tested by means of a static strength test. Endurance was tested by use of the ergograph and twenty percent of the maximum strength of the knee extensors was used as the load.

Both static and phasic exercise groups exhibited an increase beyond the 0.01 level of confidence in strength and endurance. Mean gain differences of the static and phasic groups were compared in strength and endurance. The static exercise groups demonstrated a gain in strength over the phasic group which was significant beyond the 0.01 level of confidence. However, the phasic exercise group demonstrated an

endurance gain over the static exercise group which was significant beyond the 0.05 level of confidence.

Tuttle, Janney, and Salzano (29) utilized dynamometers based on the strain gauge principle for measuring the maximum strength and endurance of the back and leg muscles. Two phasic strength-endurance indices were obtained: an absolute index, as the total area of contractile curve maintained for a specified time; and a relative index, as the average strength maintained for the given time. They found that the correlation between maximum strength and the absolute strength endurance index was 0.90.

In another study by Tuttle, Janney, and Thompson (30) the relationship between grip strength and grip endurance was investigated. Data were collected from 200 university men between the ages of twenty and thirty years. The percentage of the maximum grip strength which was maintained for one minute (strength endurance) was correlated with maximum grip strength. The coefficient for the right hand was -0.40 and for the left, -0.41. This suggests that stronger individuals can maintain a smaller proportion of their maximum strength than those with less initial strength. However, a correlation of maximum strength with the strength endurance index gave a coefficient of 0.67 for the right hand, and 0.66 for the left. This indicates that the individuals with the greater maximum strength have a greater strength

endurance index.

Elbel (14) studied the relationship between leg strength, leg endurance and other body measurements. Five hundred-ninety potential pilots and pilots were divided into four groups. Especially designed apparatus was used for securing data relative to leg strength and leg endurance. Low but significant coefficients of correlation were found between leg endurance and leg strength for these groups. Considering the measurements for each leg as to significance, there was little consistency in the coefficients of correlation between leg strength and leg endurance. Data for the right leg for the group of pilots gave significant coefficients of correlation between leg strength and leg endurance at all increments.

Hansen (17) trained seven subjects by using ten maximal resistance phasic exercises a day for five weeks. Before and after the training period of phasic strength, static strength, phasic strength, and phasic and static endurance were tested. As a result, Hansen found that training phasically increased phasic and static strength, but no significant increase in static or phasic endurance resulted.

Howell, Kimato, and Morford (19) determined the relative effects of a static exercise program, the Commander Set of static exercises, and a regular phasic exercise program of weight training upon muscular endurance as measured by two-minutes of all-out work on a bicycle ergometer at 14

kilograms resistance. Both experimental groups showed statistically significant improvements in the bicycle ergometer test. No statistically significant differences between the means of the initial and final scores of the two experimental groups was found. They concluded that increases in muscular endurance may be effected by certain programs of static contractions as well as phasic.

Dennison, Howell, and Morford (11) found that both the phasic and static exercise programs brought about significant increase in endurance. The difference between the two groups were not significantly different.

CHAPTER III

METHODS AND PROCEDURES

I. SUBJECTS

Twenty subjects were selected from the required physical education program and staff at the University of Montana. Only subjects who had no recent experience in phasic or static exercise training were selected. The subjects were in good physical condition and without any injuries to their right arm or shoulder. The physical characteristics are shown in Table I.

TABLE I
PHYSICAL CHARACTERISTICS OF SUBJECTS

Subjects	Weight Pounds	Height Inches	Age Years
G. A.	180	72	19
L. B.	174	72	20
W. B.	157	75	18
L. C.	160	70	23
R. F.	147	70	19
R. G.	207	80	21
G. K.	150	69	18
S. K.	160	70	18
R. L.	180	71	18
G. M.	180	69	18
R. M.	200	72	22
J. N.	135	67	19
C. O.	185	70	27
R. P.	150	70	20
T. S.	110	65	19
B. S.	157	70	27
D. T.	170	71	19
L. W.	120	65	18
J. R.	208	72	22
S. T.	160	70	23

II. SELECTION OF EQUIPMENT FOR STRENGTH AND ENDURANCE MEASUREMENT

One of the most objective instruments for measuring static muscular strength and static muscular endurance is the cable tensiometer. Clarke (4) compared objectivity coefficients and found the cable tensiometer had greater precision than either a strain guage or spring scale. An objectivity coefficient of 0.96 was quoted by Clarke for measuring elbow flexion. Cable tension is determined by measuring the force needed to create an offset on a riser in a cable stretched between two points or sectors. A pointer registers the amount of tension pounds. Tension pounds may be converted directly into pounds by use of a calibration chart or calibration curve. Twenty-eight strength tests based on movements of the wrist, elbow, shoulder, knee, and ankle were originally proposed by Clarke. A later study (6) changed the total number of tests to thirty and changed many of the joint angles and body positions.

Donnelly and Hunsicker (12) substantiated Clarke's objectivity coefficient for the tensiometer. They state, "In comparing objectivity coefficients it was found that the cable tensiometer had greater precision than either a strain guage, spring scale, or myometer."

A cable-pulley apparatus was found to be applicable for testing phasic muscular strength and endurance. This

apparatus consisted of a handle grasped by the subject which was attached to a pulling assembly. The cable extended horizontally to the subjects arm and ran to a pulley at the foot-end of the table. Then it ran downward to where it connected with the weight platform. By placing changeable weights on the platform, the amount lifted by the subject was controlled. With this apparatus the subject performed the same movements as in a one arm curl. In a pilot study using six subjects, this apparatus had a test-retest reliability of 0.91 from trial one to trial two.

III. SELECTION OF MUSCLE GROUP AND POSITION FOR TESTING

The elbow flexors were selected for testing phasic and static muscular strength and phasic and static muscular endurance. Clarke (8) obtained the best reliability when testing the elbow flexors. Rasch (24), Downer (13), and others (20, 15, and 2) found this to be true also. A most important reason for the designation of the elbow flexors is the large amount of research available on the best position for the forearm in testing. Clarke (7) published an article which summarizes this research. The points brought forth in this article were incorporated in this study.

In testing for endurance, consistent results could only be achieved when exhaustion occurred in about two min-

utes. An identical load could not be used for all subjects in such testing if repeatable results were to be obtained. Thus, it became necessary to adapt the amount of the load for each individual. The procedure found to be effective in determining this amount was to take a proportion of the strength of the muscles to be exercised. In initial ergographic endurance testing of the elbow flexor muscles, a load equal to three-eighths proportion of the maximum strength of these muscles, with a cadence of thirty repetitions per minute, resulted in a test-retest correlation of 0.85 (7).

The work output of muscles in exhaustion performances is greater when they are in position to apply greatest tension at the point of greatest stress. The strongest position for the application of the maximum strength of the elbow flexor muscles is with the forearm midway in the range of motion of the elbow joint, between 100 and 140 degrees. A decrease of approximately twenty-eight per cent in the ability of these muscles to apply tension occurs when the forearm is fully extended at 180 degrees (9). Hunsicker and Greey (20), and Downer (13) found the maximum strength of the elbow flexors to be at 90 degrees. It was decided to use an angle of 100 degrees for the static test in this study.

The speed of muscular contraction affects muscular endurance performance. There appears to be a specific combination of load and cadence which produces maximum work out-

put of each muscle group. For elbow flexion an effective cadence or speed of muscular contraction was found to be thirty complete repetitions per minute (7).

Rasch (24), Downer (13), and Hunsicker and Greey (20), as well as Clarke (8), found that there were variations in maximum strength when the forearm was in pronation, supination, and the mid-position. Because of the arrangement of the apparatus and the high coefficient found by Clarke (8) for supination (0.92); this position was adopted for the testing of phasic and static muscular strength and phasic and static muscular endurance. All of the studies cited above found a similar high correlation of coefficient for supination.

IV. EQUIPMENT AND APPARATUS

The phasic muscular strength and phasic muscular endurance testing apparatus used is described below. Static muscular strength and static muscular endurance test measurements were taken according to Clarke's (8) directions with similar equipment to that he described. This equipment is described in the following paragraphs also.

Testing table. The testing table was approximately eight feet by two feet. It consisted of a pulley apparatus at the foot-end and to one side. A foot board which was adjustable to the subject was directly in front of the pulley apparatus. An arm support was adjustable so that the sub-

FIGURE 1. TESTING TABLE

ject could place his right arm in the most comfortable position. An adjustable shoulder brace kept the subject from sliding during exertion. Also, an adjustable block restricted the phasic movement to a certain number of degrees. The position of the adjustable apparatus was recorded by the number of the hole in which it was placed. A strap was in position to limit the lifting of the right arm from the table. An open-eye screw hook was located at the foot-end of the table to which the static pulling assembly was connected. This table enabled the subjects to be in the same position for each test and limited, as much as possible, the use of any other muscle groups (see Figure 1).

Phasic chain and snap pulling assembly. A forty-six inch piece of one-sixteenth inch flexible cable was attached to two safety hooks, one at each end. An eighteen inch link chain was attached to the cable. A swivel snap connected the pulling assembly to the grip handle. Another swivel snap connected the pulling assembly to the weight platform. The pulling assembly ran from the subject horizontally to the pulley and down to the weight platform.

Weight platform. The platform consisted of a circular base six inches in diameter. A three-quarter inch rod extended twelve inches perpendicular to the base and attached to the center of the base. An eye-bolt was screwed into the top of the rod which attached the swivel snap to the pulling assembly. This apparatus weighed four and one-half pounds.

Weights. The weights were olympic standard weights and were checked for accuracy. The weights consisted of:

- 2 - One-and-one-quarter pound weights
- 4 - One-and-one-half pound weights
- 2 - Two-and-one-half pound weights
- 2 - Five pound weights
- 6 - Ten pound weights

Any combination within one-quarter of a pound was possible with the above weights.

The cable tensiometer. The cable tensiometer measures strength by measuring the tension on a cable due to a force exerted by the subject.

Static chain and snap pulling assembly. A short piece (12 to 18 inches) of one-sixteenth inch flexible cable was attached to a link chain approximately three feet long. A safety hook was fastened to the cable and connected the cable to the grip handle. The cable tensiometer was placed on this cable in order to record the static strength force exerted by the subject.

Grip handle. The subject grasped the pulling assembly by the grip handle. This handle was constructed from cast iron metal, shaped in the form of a horseshoe. A round wooden grip fit into the open ends by a rod. This was then grasped by the subject.

Goniometer. A goniometer was used to measure the joint angle at which force was to be applied by the subjects. This instrument is a plexiglass protractor with a fixed arm

attached to its base line, and an adjustable arm attached to the mid-point of the base line. The angle was measured by moving the adjustable arm in relation to the fixed arm.

Metronome. A metronome was used to set the cadence for contraction during phasic endurance testing. The metronome was set at sixty beats per minute.

Stop watch. A stop watch was used to record the time of the static endurance contraction. Readings were attainable to one-tenth of a second.

V. METHODS OF GIVING TESTS

Maximum phasic strength. Maximum phasic strength was tested by the maximum amount of weight the subject could elevate one time. The subject was placed in a supine position with his hips and knees flexed and his feet resting on the table and against the foot board. His free hand was placed on his chest. The subject's upper right arm was adducted to a position alongside the body and resting on the supporting surface. His elbow was placed in 160 degrees of flexion and his forearm in a supine position. The handle was gripped by the subject and attached to the pulling assembly. A strap was placed over the right arm just above the elbow joint. It was fastened so as not to restrict normal flexion of the arm. The cable ran from the handle horizontally to the pulley and then down to the weights. The tester would instruct the subject to pull exclusively with the forearm. The sub-

ject would contract until he touched the block which was placed for sixty degrees flexion.

The maximum weight the subject could elevate one time through the range of motion was obtained. This was found by trial and error. A minimum of three minutes was allowed between trials. Berger (1) found that a two minute resting period was sufficient for full recovery between tests. No more than four trials were necessary to obtain the individual's maximum phasic strength.

Maximum static strength. The subject was placed in the same position as for the maximum phasic strength test except his elbow was placed in 100 degrees of flexion. The subject grasped the handle and the pulling assembly was connected to the eye-hook at the end of the table. The tester, while holding the tensiometer in place, would instruct the subject to pull exclusively with the forearm, not raising his head, his shoulders or his hips.

Phasic muscular endurance. The subject was placed in the same position as for the maximum phasic strength test. Three-eighths of the subject's maximum phasic strength was calculated and placed on the weight platform. With the elbow in 160 degrees of flexion the subject grasped the handle and pulled to sixty degrees of flexion. The metronome was started with a sixty beat per minute rhythm. The subject flexed to one beat and extended the elbow to the next beat, which resulted in thirty contractions per minute. The sub-

ject was encouraged to keep to the rhythm. Once the subject could no longer continue to the rhythm, he discontinued the effort. The number of contractions were then recorded.

Static muscular endurance. The subject was placed in the same position as for the maximum static strength test with the arm in 100 degrees of flexion. Three-eighths of the maximum static strength was calculated. The subject exerted enough tension on the tensiometer to keep it at that particular level. The subject continued this until he could no longer keep it at the three-eighths level. The time that the subject kept the tensiometer at this level was recorded.

VI. EXPERIMENTAL PROCEDURES

The subjects were tested by appointment on Monday through Friday. The first testing appointment was designed to familiarize each subjects with procedures of the test and to give the tester an idea of the subject's maximum phasic strength.

When a subject arrived at the laboratory, he disrobed and recorded his weight. Next, the subject completed the personal information sheet while the tester briefed him as to what was expected of him during the testing. He then redressed and took his position on the table. The subject's proper position was found for that particular test. These positions were recorded by noting the number of the hole in which the adjustable apparatus was located. The link of chain

to which the swivel snap attached was also recorded. Each time the subject was tested he was placed in the same position.

Approximately four subjects were tested per hour. Each subject was tested twice in all tests. The subject was given a rest period of no less than three minutes nor more than six minutes between trials on any of the maximum strength tests. No more than two tests were administered at any one testing period. The maximum phasic strength test and maximum static strength test were administered to all subjects prior to the other tests. This was necessary because the endurance tests were dependent upon the results of the maximum strength tests. In testing maximum strength ten subjects followed this schedule:

- Test Period I
 - Trial 1 - Maximum static strength
 - Trial 1 - Maximum phasic strength
- Test Period II
 - Trial 2 - Maximum phasic strength
 - Trial 2 - Maximum static strength

The other ten subjects were tested in reverse order to the above. Upon the completion of both trials of the maximum strength tests, the phasic muscular endurance and static muscular endurance tests were administered. Only one endurance test was given on any particular day. This was due to the long recovery period needed. In testing muscular endurance ten subjects followed this schedule:

- Test Period III
 - Trial 1 - Phasic muscular endurance

Test Period IV
 Trial 1 - Static muscular endurance

Test Period V
 Trial 2 - Phasic muscular endurance
Test Period VI
 Trial 2 - Static muscular endurance

The other ten subjects were tested in reverse order to the above.

VII. INTERPRETATION OF SCORES

All tests were administered twice. In view of the facts presented by Whitley and Smith (31), it seems that the practice of using the best of several performance scores in preference to using the individual averages does not rest on a sound foundation. It was found that in strength tests the average score was the best. The static strength test results were converted into pounds through the use of a conversion chart (see Appendix, page 46), and the mean value of these two scores calculated and then recorded as the strength of the elbow flexors. This same procedure was adopted for the other tests.

CHAPTER IV

ANALYSIS AND DISCUSSION OF RESULTS

I. METHOD OF ANALYSIS

Pearson's Product-Moment Coefficient of Correlation was used to evaluate the relationship between maximum phasic and static strength and phasic and static muscular endurance. This same test was used to test the reliability of trial one and trial two in maximum phasic and static strength and phasic and static muscular endurance. Since the data was ungrouped and there was a small sample (twenty), Garrett's (16) coefficient of correlation when deviations are taken from the assumed means of the two distributions was used. Garrett's (16) formula is:

$$r = \frac{\frac{\sum x'y'}{N} - C_x C_y}{\sigma_x \sigma_y}$$

Where r = The coefficient of correlation when deviations are taken from the assumed means of the two distributions.

$\sum x'y'$ = Sum of the product of the difference of the actual score and the assumed mean.

N = Number of subjects in sample.

C_x = Difference between the actual mean and assumed mean of test x .

C_y = Difference between the actual mean and assumed mean of test y .

σ_x = Standard deviation of test x .

σ_y = Standard deviation of test y .

The standard error of the mean measures the degree to which the mean is affected by the errors of measurement as well as by errors of sampling. The standard error of the mean was computed by the following formula (16):

$$s_m = \frac{s}{\sqrt{N}}$$

Where s_m = Standard error of the mean in small samples.

$$s = \sqrt{\frac{\sum x^2}{(N-1)}}$$

N = The size of the sample.

To discover whether maximum phasic and static strength and phasic and static muscular endurance differed sufficiently in mean performance to enable one to say with confidence that there is a difference between the means of the populations from which the samples were drawn, it was necessary to know the standard error of the difference between the sample means. The standard error of the difference between the means was computed using the following formula (16):

$$SE_d = \sqrt{\sigma_{m_1}^2 + \sigma_{m_2}^2 - 2r_{12}\sigma_{m_1}\sigma_{m_2}}$$

Where SE_d = Standard error of the difference between correlated means.

σ_{m_1} = Standard deviation of mean one.

σ_{m_2} = Standard deviation of mean two.

r_{12} = Coefficient of correlation from test x and test y.

The "t" test was used to determine the levels of significance (16).

Where t = Difference between means divided by the standard error of the difference.

According to Garrett's (16) table of "t", for use in determining the significance of statistics, the degrees of freedom are (N-1) or 19.

TABLE II
GARRETT'S TABLE OF t

Degrees of freedom	0.05	0.01
19	2.54	2.86

II. ANALYSIS OF RESULTS

The reliability of the maximum static and phasic strength and static and phasic muscular endurance tests are shown in Table III. This was based upon the first and second trials of the test preceded by a training test for each condition. Included in Table III are the standard error of the difference of the means of trial one and trial two. All tests had a statistically significant coefficient from trial one to trial two.

The various relationships between maximum static and phasic strength and static and phasic muscular endurance are

TABLE III
BASIC STATISTICS FOR STATIC AND PHASIC
STRENGTH AND ENDURANCE

Test	Mean Trial No. 1	Mean Trial No. 2	Mean	Stand. Devia- tion	Reliability of Tests*	t
Maximum phasic strength (lbs.)	44.3	45.3	44.8	5.56	0.88	0.02
Maximum static strength (lbs.)	56.0	57.2	56.6	6.39	0.88	0.01
Phasic muscular endurance (rep.)	41.2	44.4	42.8	7.37	0.80	2.62**
Static muscular endurance (sec.)	78.9	78.7	78.8	14.28	0.87	0.15

*The reliabilities of the tests were determined using the first and second trials.

**Statistically significant at the 0.05 level.

TABLE IV
RELATIONSHIPS OF STATIC AND PHASIC STRENGTH
AND STATIC AND PHASIC ENDURANCE

Test	Coefficient of Correlation
Maximum phasic strength to maximum static strength.....	0.77*
Maximum phasic strength to phasic muscular endurance.....	0.04
Maximum phasic strength to static muscular endurance.....	-0.37
Maximum static strength to static muscular endurance.....	-0.42
Maximum static strength to phasic muscular endurance.....	0.05
Phasic muscular endurance to static muscular endurance.....	-0.16

*Statistically significant at the 0.01 level.

shown in Table IV. The subjects, in strength testing, exerted a mean maximum phasic contraction of 44.8 pounds, with a standard deviation of 5.6 pounds, and a mean static tension of 56.6 pounds, with a standard deviation of 6.4 pounds.

A coefficient of correlation of 0.77 was obtained between maximum phasic and maximum static muscular strength. Using Garrett's (16) Table of Levels of Significance of Correlation Coefficients, "r" was found to be statistically significant at the 0.01 level. According to Table V the levels of significance were as follows:

TABLE V
CORRELATION COEFFICIENTS AT THE 5% AND 1%
LEVELS OF SIGNIFICANCE

Degrees of freedom (N-2)	0.05	0.01
18	.444	.561

A "t" test was computed to evaluate the significance of the difference between the means of maximum phasic strength and maximum static strength. The difference of 11.8 pounds was statistically significant at the 0.01 level.

The maximum phasic strength contractions ranged from 34.25 pounds to 53.75 pounds. A coefficient of 0.67 was obtained for the relationship between maximum phasic strength and the weight of the subjects. This was statistically sig-

GRAPHIC REPRESENTATION OF THE CORRELATION COEFFICIENTS

FIGURE 2

FIGURE 3

FIGURE 4

FIGURE 5

nificant.

A number of studies have reported a relationship between strength and endurance. In the endurance testing the subjects exerted a mean phasic endurance of 42.6 repetitions, with a standard deviation of 7.4 repetitions, and a mean static endurance tension of 78.8 seconds, with a standard deviation of 14.3 seconds.

Phasic muscular endurance ranged from 31.5 repetitions to 59.5 repetitions for the mean of the two trials. Static muscular endurance ranged from 61 seconds to 114.5 seconds for the mean of the two trials.

In relating maximum phasic strength and phasic endurance a coefficient of 0.04 was obtained. Maximum phasic strength in relation to static endurance was found to have a coefficient of -0.37. This also was of no statistical significance. The relationship between maximum static strength to static endurance was of no significance with a coefficient of -0.42. The relationship of maximum static strength to phasic muscular endurance had a coefficient of 0.05. In relating phasic endurance to static endurance the coefficient was -0.16. In no way was phasic or static muscular endurance found to be related to each other or to maximum static or phasic strength.

III. DISCUSSION OF RESULTS

A significant relationship was obtained between maximum phasic strength and maximum static strength (0.77). This was in agreement with Berger (1) who obtained a coefficient of 0.67 between maximum phasic strength and maximum static strength. Mathews and Kruse (21) found that greater static muscular tension can be developed than can phasic muscular tension. In this study the mean static tension was 11.8 pounds more than the mean phasic contraction. Although there is a statistically significant difference between the means, a high degree of relationship remains between maximum phasic and static strength. A "t" test used to evaluate the difference between the means of maximum phasic and static strength was 12.69. This was statistically significant at the 0.01 level.

It is concluded, that in the testing procedure used in this study, there appears to be a large difference between the amount of tension which could be recorded in a single maximum static elbow contraction and the amount of weight which may be handled in a single maximum phasic elbow flexion.

Berger's (1) conclusion that a phasic strength test should be used to determine strength changes due to phasic training, and that a static test should be used to measure strength changes due to static training seems to be supported by this study. The static strength test has been used con-

siderably more since it is easier to record maximum strength with the use of a tensiometer. Since there is a high degree of relationship between maximum static and phasic strength, researchers have felt justified in using only one test to measure improvement. However, since the strength scores differed significantly, Berger's conclusion would seem in order.

Most researchers are in agreement that strength is related to the body weight. A statistically significant relationship (0.01) was obtained between maximum phasic strength and the weight of the subjects. On the other hand a coefficient of 0.44 was obtained for the relationship between maximum static strength and the weight of the subjects. This was of no statistical significance at the 0.05 level.

A number of researchers, including Clarke (3) and Elbel (14), have stated that strength is related to endurance. In a thorough review of the literature in this area no study was found that related phasic endurance to maximum phasic strength or static muscular endurance to maximum static strength. In addition, no one had related phasic muscular endurance to static muscular endurance.

In relating maximum phasic strength to phasic muscular endurance a coefficient of 0.04 was obtained which was not statistically significant. In relating maximum static strength to static muscular endurance a coefficient

of -0.42 was obtained. This, too was of no statistical significance. Tuttle, Janney, and Thompson (30) found that maximum grip strength correlated to the percentage of the maximum grip strength maintained for one minute (strength endurance) by a coefficient of -0.40 for the right hand and -0.41 for the left. Elbel (14), in contradiction, found low but significant coefficients of correlation between leg endurance and leg strength.

One explanation for the lack of relationship in this study may be the fact that phasic and static muscular endurance testing was based on $3/8$ of the subject's maximum phasic and static strength.

Hansen (17) concluded that training phasically increased phasic and static strength, but no significant increase in phasic or static endurance resulted.

Finding no relationship in phasic and static strength to static and phasic endurance, a linear correlation was conducted on phasic endurance to static endurance. The result was a coefficient of -0.16 .

It was surprising to find most of the coefficients of correlation to be negative or very low positive. Even though the literature is not in agreement on the relationship of maximum strength to endurance there is an indication that there is a slight degree of relationship. This study does not substantiate this conclusion.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

I. SUMMARY

It was the purpose of this study to investigate the relationship between maximum phasic strength, maximum static strength, phasic muscular endurance and static muscular endurance. Specifically, maximum phasic strength was correlated to maximum static strength, maximum phasic strength was correlated to phasic muscular endurance, maximum static strength to static muscular endurance and phasic muscular endurance to static muscular endurance.

Maximum phasic muscular strength was determined by the amount a subject could move 100 degrees in elbow flexion. Maximum static strength was determined by the amount of tension a subject could exert. This was measured by the cable tensiometer. Phasic muscular endurance was measured by the number of contractions of the elbow flexors at a rate of thirty contractions per minute, with a load of three-eighths of the maximum phasic strength. Static muscular endurance was determined by the amount of time the subject could exert sufficient force by sustained contraction of the elbow flexors to hold the tensiometer indicator at three-eighths of the maximum static strength.

The data was obtained from twenty subjects who were

selected from the required physical education program and staff at the University of Montana. The subjects were familiarized with the testing procedure on their first visit to the laboratory. The subjects were then tested twice in each of the four tests. Coefficients of correlation were conducted on the reliability of each test. The mean of the two trials was used in correlating strength and endurance measures.

The reliability of the tests was presented in Table form as well as the relationships of the various tests (Table III and IV). Pearson's Product-Moment Coefficient of Correlation was used to test the reliability and relationships of the tests. Garrett's (16) Table of Levels of Significance was used to test the null hypothesis.

It was found that:

1. A statistically significant correlation of coefficient of 0.77 was obtained between maximum phasic strength and maximum static strength.
2. There is a large difference between the amount of tension which could be recorded in a single maximum static elbow contraction and the amount of weight which may be handled in a single maximum phasic elbow flexion.
3. Maximum phasic strength and phasic muscular endurance do not correlate significantly (0.04).

4. The relationship between maximum static strength and static endurance was of no significance with a coefficient of -0.42 .
5. In relating phasic endurance to static endurance the coefficient was -0.16 . This was of no statistical significance.
6. Maximum phasic strength related significantly to the weight of the subjects but maximum static strength displayed no significant relationship to the weight of the subjects.

II. CONCLUSIONS

On the basis of the findings of this study the following conclusions were made:

1. Maximum phasic strength and maximum static strength, though significantly correlated, are sufficiently different to warrant the use of separate tests to measure the improvement of strength resulting from static and phasic training.
2. Maximum phasic strength has no relationship to phasic muscular endurance.
3. Maximum static strength has no relationship to static muscular endurance.
4. Phasic muscular endurance and static muscular

endurance are not related. In no way was phasic or static strength related to phasic or static muscular endurance.

III. RECOMMENDATIONS

In view of the findings and conclusions from this study, the following recommendations have been made.

1. Different percentages of maximum strength should be used to test the effects this has on the correlation coefficient of maximum strength to static and phasic muscular endurance.
2. A study should be conducted in which other muscle groups are correlated as in this study to determine if there would be any change.
3. A study should be conducted in which the same testing procedures are used and then followed by a training period to see if the results change significantly.

SELECTED BIBLIOGRAPHY

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1. Berger, Richard A. "Comparison of Static and Dynamic Strength Increases," Research Quarterly, 33:329-33, October, 1962.
2. Capen, E. K. "The Effect of Systematic Weight Training on Power, Strength and Endurance," Research Quarterly, 21:83-93, May, 1950.
3. Clarke, H. Harrison. Application of Measurement to Health and Physical Education. Third edition. Englewood Cliffs: Prentice-Hall, Inc., 1959.
4. Clarke, H. Harrison. "Comparison of Instruments for Recording Muscle Strength," Research Quarterly, 25:398-411, December, 1954.
5. Clarke, H. Harrison. "Development of Volitional Muscle Strength as Related to Fitness," Exercise and Fitness. Chicago: The Athletic Institute, 1959, pp. 200-213.
6. Clarke, H. Harrison. "Improvement of Objective Strength Tests of Muscle Groups by Cable-Tension Methods," Research Quarterly, 21:399-419, December, 1950.
7. Clarke, H. Harrison. "Muscular Strength Endurance Relationships," Archives of Physical Medicine and Rehabilitation, 38(9):584, September, 1957.
8. Clarke, H. Harrison. "Objective Strength Tests of Affected Muscle Groups Involved in Orthopedic Disabilities," Research Quarterly, 19:118-147, May, 1948.
9. Clarke, H. Harrison. "Single Bout Elbow Flexion and Shoulder Flexion Ergography Under Conditions of Exhaustion Testing," Archives of Physical Medicine and Rehabilitation, 34:240, April, 1953.
10. Cureton, T. K. "The Unfitness of Young Men in Motor Fitness," The Journal of the American Medical Association, 123(2):53, September, 1949.
11. Dennison, J. D., M. L. Howell and W. R. Morford. "Effect of Isometric and Isotonic Exercise Programs Upon Muscular Endurance," Research Quarterly, 32:348-52, December, 1961.

12. Donnelly, Richard J. and Paul A. Hunsicker. "Instruments to Measure Strength," Research Quarterly, 26:408-419, December, 1955.
13. Downer, Ann H. "Strength of the Elbow Flexor Muscles," The Physical Therapy Review, 33:68-69, February, 1953.
14. Elbel, E. R. "Relationship Between Leg Strength, Leg Endurance, and Other Body Measurements," Journal of Applied Physiology, 2:197-107, October, 1949.
15. Elkins, E. C., U. M. Leden and K. G. Wakim. "Objective Recording of the Strength of Normal Muscles," Archives of Physical Medicine, 32:639-647, October, 1951.
16. Garrett, Henry E. Statistics in Psychology and Education. New York: Longmans, Green and Co., 1958.
17. Hansen, J. "The Training Effect of Dynamic Maximal Resistance Exercises," Abstracted by Richard R. Montpetit, Index and Abstracts of Foreign Physical Education Literature, 8:60, 1963.
18. Hettinger, T. and E. H. Müller. "Muskelleistung and Muskeltraining," Arbeitsphysiologie, 15:2, October, 1953.
19. Howell, Maxwell L., Ray Kimato and W. R. Morford. "Effect of Isometric and Isotonic Programs Upon Muscular Endurance," Research Quarterly, 33:536-40, December, 1962.
20. Hunsicker, Paul A. and G. Greey. "Studies in Human Strength," Research Quarterly, 28:109-119, March, 1957.
21. Mathews, Donald K. and Robert Kruse. "Effects of Isometric and Isotonic Exercises on Elbow Flexor Muscle Groups," Research Quarterly, 28:26-37, March, 1957.
22. Mitchem, John T. "Isometric Exercise-An Evaluation," Physical Educator, 20(3):128-9, October, 1963.
23. Morehouse, Laurence E. "Physiological Basis of Strength Development," Exercise and Fitness. Chicago: The Athletic Institute, 1959, pp. 193-198.

24. Rasch, Phillip H. "Effect of Position of Forearm on Strength of Elbow Flexion," Research Quarterly, 27:333-337, October, 1956.
25. Rasch, Phillip H. "Strength Relationship Between Maximum Isometric Tension and Maximum Isotonic Elbow Flexion," Research Quarterly, 28:85, March, 1957.
26. Rasch, Phillip H. and L. E. Morehouse. "Effect of Static and Dynamic Exercise on Muscular Strength and Hypertrophy," Journal of Applied Physiology, 11:29-34, January, 1957.
27. Salter, Nancy. "The Effect of Muscle Strength of Maximum Isometric and Isotonic Contractions at Different Repetition Rates," Journal of Physiology, 130:109-113, October, 1955.
28. Sullivan, George M. "The Effects of Isotonic and Static Contractions of the Quadriceps on Strength and Endurance." Unpublished Master's thesis, Washington State University, Pullman, 1961.
29. Tuttle, W. W., C. D. Janney, and J. V. Salzano. "Relation of Maximum Back and Leg Strength to Back and Leg Endurance," Research Quarterly, 26:96-106, March, 1955.
30. Tuttle, W. W., C. D. Janney and C. W. Thompson. "Relation of Maximum Grip Strength and Grip Strength Endurance," Journal of Applied Physiology, 2:663-670, June, 1950.
31. Whitley, J. D. and L. E. Smith. "Strength-Larger Correlations Obtained by Using Average Rather Than Best Scores," Research Quarterly, 34:248, May, 1963.

APPENDIX

APPENDIX A

CALIBRATION OF TENSIOMETER

Riser No.		Tension Lbs.	Riser No.		Tension Lbs.
5	***	10.0	36		51.0
6		11.0	37		52.5
7		12.5	38		54.0
8		13.5	39		55.0
9		15.0	40	***	56.5
10	***	16.0	41		58.0
11		17.5	42		60.0
12		18.5	43		61.5
13		20.0	44		63.0
14		21.0	45	***	65.0
15	***	22.5	46		66.5
16		24.0	47		68.0
17		25.0	48		70.0
18		26.0	49		72.0
19		27.5	50	***	75.0
20	***	28.5	51		77.0
21		30.0	52		80.0
22		31.0	53		82.0
23		32.5	54		85.0
24		33.5	55	***	87.0
25	***	35.0	56		90.0
26		36.5	57		92.0
27		38.0	58		95.0
28		40.0	59		97.0
29		41.0	60	***	100.0
30	***	42.5			
31		43.5			
32		45.0			
33		46.5			
34		48.0			
35	***	50.0			

APPENDIX B

SAMPLE STRENGTH QUESTIONNAIRE

This questionnaire is designed to eliminate any extraneous factors which might influence your result on the strength and endurance tests. Please answer this questionnaire as honestly as possible. Thank you.

NAME _____ DATE _____

AGE _____ HEIGHT _____ WEIGHT _____ TIME _____

1. Are you, or have you, participated in any organized athletic events in the last month?
2. Are you, or have you, participated in a program of weight lifting in the last three months?
3. Have you participated in any strenuous activity in the last 24 hours? If so, what did this consist of?
4. Has anything occurred in the last 24 hours that you feel may affect your ability to apply maximum strength? (emotional or physical) If yes, would you describe?
5. Briefly describe your last meal and when you ate it.
6. Have you had any recent illness which might possibly affect your strength (flu, cold, strep throat, etc.)?
7. Do you have any soreness, stiffness or any other injury to your right hand, arm or shoulder? If yes, would you describe?

APPENDIX C

TABLE VI

COLLECTION OF DATA FOR MAXIMUM STRENGTH TESTING

Subject	Maximum		Phasic		Strength		Maximum		Static		Strength	
	Trial	No. 1	Trial	No. 2	Mean		Trial	No. 1	Trial	No. 2	Mean	
G. A.	55.0		52.5		53.75		63.00		61.50		62.25	
L. B.	50.0		50.0		50.00		66.50		75.00		70.75	
W. B.	42.5		42.5		42.50		55.00		55.00		55.00	
L. C.	46.0		50.0		48.00		60.00		60.00		60.00	
R. F.	32.5		36.5		34.50		48.00		46.50		47.25	
R. G.	51.0		54.0		52.50		60.00		65.00		62.50	
G. K.	40.0		39.0		39.50		51.00		52.50		51.75	
S. K.	42.5		40.0		41.25		50.00		51.00		50.50	
R. L.	47.5		50.0		48.75		61.50		68.00		64.75	
G. M.	45.0		47.5		46.25		66.50		61.50		64.00	
R. M.	50.0		47.5		48.75		63.00		58.00		60.50	
J. N.	39.0		42.5		40.75		52.50		50.00		51.25	
C. O.	41.0		40.0		40.50		46.50		54.00		50.25	
R. P.	45.0		45.0		45.00		55.00		53.00		54.00	
T. S.	33.5		35.0		34.25		44.00		41.00		42.50	
B. S.	46.5		47.5		47.00		58.00		61.50		59.75	
R. T.	49.0		50.0		49.50		60.00		64.00		62.00	
L. W.	40.0		42.5		41.25		51.00		51.00		51.00	
J. R.	50.0		50.0		50.00		55.75		60.75		58.25	
S. T.	40.0		42.5		41.25		52.50		55.50		54.00	

APPENDIX D

TABLE VII

COLLECTION OF DATA FOR MUSCULAR ENDURANCE TESTING

Subj.	3/8 of max. phasic strength (lbs.)	Phasic Muscular Endurance		3/8 of max. Sta. strength (lbs.)	Static Muscular Endur.	
		Trial No. 1	Mean (reps.)		Trial No. 1	Mean (secs.)
G. A.	20.0	52	59.5	23.0	64	64.5
L. B.	19.0	40	41.5	27.0	69	69.5
W. B.	16.0	33	34.5	21.0	70	70.5
L. C.	18.0	37	40.5	33.0	98	92.0
R. F.	13.0	44	44.0	18.0	91	88.5
R. G.	20.0	39	37.5	23.0	78	76.5
G. K.	15.0	34	35.0	19.0	81	85.5
S. K.	16.0	40	41.0	19.0	84	84.0
R. L.	18.0	40	39.0	24.0	70	67.5
G. M.	17.0	49	51.5	24.0	68	71.5
R. M.	18.0	50	49.5	23.0	72	75.0
J. N.	15.0	40	41.0	19.0	98	95.5
C. O.	15.0	46	45.0	19.0	61	61.0
R. P.	17.0	38	39.0	20.0	115	114.5
T. S.	13.0	49	51.5	16.0	90	94.0
B. S.	18.0	32	31.5	22.0	86	82.0
R. T.	18.0	45	52.5	23.0	61	66.0
L. W.	15.0	42	43.5	19.0	98	94.0
J. R.	19.0	28	32.0	22.0	60	61.5
S. T.	15.0	45	45.5	20.0	64	64.0