8-1-1966

An Investigation of Selected Strength Test Results as Related to Weight Changes on High School Varsity Wrestlers

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AN INVESTIGATION OF SELECTED STRENGTH TEST RESULTS AS RELATED TO WEIGHT CHANGES IN HIGH SCHOOL VARSITY WRESTLERS

by

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Bachelor of Science
University of North Dakota, Grand Forks, N.D., 1962

A Thesis
Submitted to the Faculty
of the
Graduate School
of the
University of North Dakota
in partial fulfillment of the requirements
for the Degree of
Master of Science

Grand Forks, North Dakota
August
1966

ACKNOWLEDGEMENTS

The writer wishes to express his appreciation to the following persons whose cooperation made this thesis possible.

He is especially grateful to Mr. Walter C. Koenig, Director of Graduate Study in Physical Education and to Dr. John L. Quaday, Chairman of the Department of Physical Education, for their guidance and counsel in completing this study. He is also grateful to Dr. Allan W. Sturges for his time spent as a member of the advisory committee.

Appreciation is also expressed to the high school students who made the collection of data for this study possible.

Finally, the writer expresses deepest appreciation and thanks to his wife for her assistance, invaluable encouragement, and patience during the writing of this thesis.

This thesis submitted by Clayton A. Johnson in partial fulfillment of the requirements for the Degree of Master of Science in the University of North Dakota is hereby approved by the Committee under whom the work has been done.

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ABSTRACT

The purpose of this investigation was to relate selected strength tests to weight changes of high school varsity wrestlers during the competitive season and after termination of wrestling training.

Eight high school varsity wrestlers were used as subjects. The subjects were tested just before the wrestling season began, twice during the season, and once following the termination of the wrestling season.

The strength tests used were the back lift, leg lift, elbow flexion, and the shoulder bar dip. The back lift and leg lift were tested with the dynamometer. Elbow flexion was tested by use of a cable tensiometer. The shoulder strength was tested by dips on the parallel bars. All raw scores were converted into Unit Strength, which was accomplished by dividing the recorded raw strength score in pounds by the weight of the individual subject.

It was found that Unit Strength of high school wrestlers does significantly increase during the competitive season. After four weeks of wrestling training the elbow flexors and shoulders showed a significant increase in Unit Strength. After

ten weeks of wrestling training all muscle groups showed a significant increase in Unit Strength except the right elbow flexors. Comparing the post-season tests with the pre-season tests, significant increases in Unit Strength were evident in all except the shoulder bar dip. The shoulder muscles had increased significantly in Unit Strength after four and ten weeks of wrestling training. Unit Strength scores were highest on the post-season tests, but when compared with weight gain, the strength increases, after the termination of wrestling conditioning and activity, were found to be insignificant.

On the basis of the findings of this study, it was concluded that significant Unit Strength increases were evident for each muscle group tested during the competitive wrestling season. It was also concluded that when accompanied by adequate physical conditioning, strength gain is not dependent upon weight changes within moderate limits. Another conclusion was that a high school wrestler can increase strength pound for pound when allowed to maintain actual normal weight, or if allowed to gain moderately within limits imposed by Minnesota High School regulations. The final conclusion was that a coach has no justification in cutting the weight of a maturing boy unless it can be proven that normal growth and development are not hindered.

CHAPTER I

INTRODUCTION

Weight control has been a problem in high school wrestling for a long time. Weight reduction, as practiced by wrestlers, is a temporary weight loss brought about by means of dehydration, withholding of food, and strenuous exercise. This practice has been condoned too frequently by coaches and parents. There has been little attention paid to the physiologic growth characteristics of teenage boys, most of whom normally would experience physical growth during a wrestling season.

Opinions differ among wrestling coaches as to whether or not weight reduction is harmful. Research studies have indicated that moderate weight losses have no harmful effects on college wrestlers. It is possible that similar studies of the effects of weight control on the immature high school wrestler would show that such weight loss does have some effect upon growth and development.

Williams, in his book, The Principles of Physical Education, cites the principle, "Physical education should appraise all the factors that locally effect the growth

and development of the individual children."[1] Concern about the weight control program, coupled with the belief that replacing fatty tissue with more dense muscle tissue by regular, vigorous practice normally would increase weight, inspired this study. This study, through the use of selected strength measurements sought to appraise the effects of weight changes on strength of the high school wrestler.

Statement of the Problem

The strength and weights of eight high school, varsity wrestlers were tested and recorded at the beginning of the wrestling season, twice during the wrestling season, and eight weeks after the termination of the wrestling season.

The purpose of this study was to relate the selected strength tests to the weight changes which took place during the season and eight weeks after the termination of the wrestling season.

The subjects were tested for strength of the shoulder, back, leg, and elbow flexion.

Need for the Study

Wrestling is a great sport and tremendous benefits may be derived by participating boys. Exces-

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[1] Jesse Feiring Williams, The Principles of Physical Education (Philadelphia: W.B. Saunders Co., 1964), p. 207.

sive weight cutting during the wrestling season or especially at tournament time places a stigma on the sport of wrestling.

Ekfelt,[2] in discussing the criticisms of high school wrestling, mentions that excessive weight reduction and irregular meals during the season are the chief targets at which criticisms of wrestling are directed, but that no proof exists of real harm done by such practices. There is, therefore, a need for a study to determine whether there are changes in strength in relation to changes in weight. If there is a definite pattern of strength changes during the course of a season, it would be an advantage for wrestlers and their coaches to know about it since they could then better plan their training programs to maintain an optimum strength level. This could also be a step in the direction toward eliminating criticisms of wrestling.

Definitions

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

Wrestling season - The wrestling season is defined as that period of time between the first day of organized wrestling practice and the last day of competition. For the 1965-66 season it lasted from

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[2]Vernon Ekfelt, "Eliminating the Criticisms of High School Wrestling," Athletic Journal, I (December, 1956), p. 10.

October 9th through February 26th.

Varsity wrestlers - These were the wrestlers who trained for and competed in varsity wrestling meets during the wrestling season.

Cable tensiometer - The cable tensiometer was the instrument used to measure the strength of the elbow flexors.

Dynamometer - The dynamometer was the instrument used to measure the strength of the back lift and the leg lift.

Unit strength - Unit strength is the term used in describing the strength of subjects as related to their weight. Unit strength was determined by dividing the recorded strength in pounds by the weight of the subject in pounds. This relationship may be demonstrated by the equation: $\frac{SE}{W} = US$ where SE = strength exerted, W = weight, and US = unit strength.

Review of Related Literature

Many studies related to wrestling have been undertaken. Most of the completed work concerning wrestling has been done in regard to the neuromuscular, cardiovascular and respiratory responses of wrestlers. Some studies related to the problem of weight control and strength have been done, but they are not as abundant as the above mentioned studies. In many of the studies in which strength was measured, it was done as a second-

ary aspect of the main problem.

Kenny,[3] in an article written in 1930, stated that by living on half to a quarter of his normal diet, a highly keyed wrestler can lose as much as ten pounds and by force of will power be strong for a full intercollegiate wrestling match. This, Kenny calls a vicious routine that cannot help the cherished aim of every athlete--namely health. As the date of this article indicates, loss of weight in wrestling has been a concern of interested individuals for quite some time. This study was concerned with collegiate wrestling, as this was the level at which the main competition in wrestling existed at the time of Kenny's article.

In 1954, Kroll[4] reported a study of the physiques of thirty-five varsity wrestlers from four "Big Ten" Universities. He compared various body measurements and strength tests of the varsity wrestlers with those of normal young men and with those of other athletic groups. He found that wrestlers were of the agility type of athlete, low in fat measurements. The wrestlers were below the average in right and left grip strengths, average in leg-lift strength, and above average in back-

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[3] H.E. Kenny, "Problem of Weight Making for Wrestling Meets," Journal of Health, Physical Education, and Recreation, XXXVI (March, 1930).

[4] Walter Kroll, "An Anthropometrical Study of Some Big Ten Varsity Wrestlers," Research Quarterly, XXV (October, 1954), pp. 307-312.

lift strength. The wrestlers were above average in vital capacity and their tissues were much more compact and dense than those of the average individual or of the other athletes with whom they were compared.

Rasch[5] administered the Total Proportional Strength Test to non-athletes, collegiate wrestlers, AAU wrestlers and Japanese champion wrestlers. No significant changes were found between mean scores of the non-athlete group and the collegiate wrestlers before and after wrestling training. The championship wrestlers were stronger than the non-wrestlers, but not significantly stronger than members of the college wrestling squad.

A strength testing experiment was reported by Clarke,[6] in which it was found that after a limited number of exhaustion bouts, there was definite and positive training effect, as determined by the increased distance an ergograph load could be moved. In this and another study reported by Clarke,[7] in which subjects

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[5]J. Rasch et. al., "Effects of Training for Amateur Wrestling on Total Proportional Strength Scores," Research Quarterly, XXXII (May, 1961), pp. 201-207.

[6]H. Harrison Clarke, "Muscular Strength--Endurance Observations from Single Bout Ergography," Journal of Association for Physical and Mental Rehabilitation, VII (January-February, 1953), pp. 8-11.

[7]H. Harrison Clarke, Clayton T. Shay and Donald K. Mathews, "Strength and Endurance (Conditioning) Effects of Exhaustion Exercise of the Elbow Flexor Muscles," Journal of Association for Physical and Mental Rehabilitation, VIII (November-December, 1954), pp. 184-188.

exercised to exhaustion during sessions approximately two minutes in length, gains in muscular strength and endurance were 11 and 13 per cent respectively, during a four week training period. He also found that strength of the elbow flexors continued to gain four weeks after the end of a four week training program.

Polo[8] studied the strength changes in eleven members of the 1964 Montana State University Wrestling Team by testing them four times during the season and once again six weeks after the end of the wrestling season with a cable tensiometer. Eight muscle groups of the shoulder, arm and hand were tested. Polo found that in each of the eight muscle groups there were significant strength changes at some time during the course of the competitive season. There was an apparent general decrease in strength throughout the first eight weeks of the season and after a week "lay off" he found a significant increase in strength in seven of the eight muscle groups. At six weeks after the termination of wrestling all muscle groups showed a significant increase in strength, with seven of the eight groups scoring higher than at any other time during the testing period.

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[8]John Francis Polo, Jr., "Strength Changes of Collegiate Wrestlers During and Following their Competitive Season" (unpublished Master's dissertation, Montana State University, 1964).

Gillum[9] investigated strength of college freshmen and varsity wrestlers on Fridays at "weigh in" time and again on Mondays after the wrestlers had regained their normal weight. The Rogers' Physical Fitness Test (PFI) was used to test the wrestlers' strength. It was found that the mean PFI for the wrestlers who reduced weight during each week was higher on Friday than on Monday. It was concluded that weight reduction did not affect strength and that wrestlers who reduced weight were stronger pound for pound than those remaining at one weight.

Hassman[10] tested the strength of twenty-seven college wrestlers just before the close of the wrestling season and retested six weeks after the end of organized wrestling practice. The change in physical status of the wrestlers was investigated between the cessation of wrestling training and the sixth week after. Significant increases occurred six weeks after cessation of training in elbow flexor strength. It was also found that increases in weight did not correlate significantly with increases in elbow flexor strength. Hassman,

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[9]Olden Curtice Gillum, "The Effects of Weight Reduction on the Body Strength of Wrestlers" (unpublished Master's dissertation, Ohio State University, 1940), cited by Polo, loc. cit.

[10]Ralph P. Hassman, "Changes in the Physical Status of Varsity and Freshman Wrestlers of the University of Oregon Following a Six Week Cessation of Organized Team Practices and Competition," (unpublished D.Ed. dissertation, University of Oregon, June, 1961).

therefore, concluded that body weight was not a factor in the increase of elbow flexor strength.

The effects of weight reduction on the strength and muscular endurance of wrestlers were studied by Bryam.[11] Once each week for five consecutive weeks, strength tests, strength-endurance tests, and a circulatory-respiratory test were administered. Bryam concluded that weight reduction up to 18.8 per cent of the body weight had no detrimental effects on the strength, circulatory-respiratory endurance, and muscular endurance of the college wrestlers tested.

Nichols[12] studied balance, reaction time, strength, power and endurance of wrestlers. These factors were felt to be important for the physical efficiency of wrestlers. Each factor was measured five times within a ten week period. It was concluded that weight loss within normal conditions and under current practices did not impair strength, slow reaction times, affect balance, adversely affect endurance or hinder wrestlers' ability to develop power.

Effects of weight loss by dehydration and withholding of food on the physiologic responses of wrestlers

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[11]Howard Bryam, "The Effects of Weight Reduction on Strength," (unpublished Master's dissertation, State University of Iowa, 1953).

[12]Harold J. Nichols, "Effects of Rapid Weight Loss on Selected Physiologic Responses of Wrestlers" (unpublished Ph.D. dissertation, University of Michigan, 1956), cited by Polo, loc. cit.

were investigated by Tuttle.[13] It was found that a wrestler may safely lose, without any noticeable loss of either strength or muscular endurance, up to five per cent of body weight by dehydration and by withholding of food.

Schuster[14] studied the effects of rapid weight reduction on endurance. Subjects who lost ten pounds in a seven day period were compared to control subjects not losing weight. Rapid weight loss was found to have no significant effect on the differences in performance of the subjects or upon the wrestling ability of the subjects.

Using four subjects, Edwards[15] investigated the effects of semi-starvation and dehydration on strength and endurance. Three subjects were used as the experimental group and one subject was used as the control. There were no significant changes found on strength tests, but a 30 per cent time decrease on the treadmill

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[13] W. W. Tuttle, "Effects of Weight Loss by Dehydration and Withholding of Food on the Physiologic Responses of Wrestlers," Research Quarterly, XIV (May, 1943), pp. 158-166.

[14] Abraham Z Schuster, "The Effects of Rapid Weight Reduction on the Endurance Performance of Wrestlers" (unpublished Master's dissertation, Pennsylvania State University, 1954), cited by Philip J. Rasch and Walter Kroll, What Research Tells the Coach about Wrestling, (Washington, D.C.: American Association for Health, Physical Education and Recreation, 1964), pp. 42-43.

[15] Jennings B. Edwards, "A Study of the Effects of Semi-starvation and Dehydration on Strength and Endurance with Reference to College Wrestling" (unpublished Master's dissertation, University of North Carolina, 1951), cited by Rasch and Kroll, loc. cit.

was found on subjects losing weight. Because of the small sample used in this study, the results were considered difficult to evaluate.

Most research done on college wrestlers seems to indicate that weight loss, even up to 18 per cent of body weight, has little effect upon the wrestler's strength and endurance. Little research of this type has been conducted using high school age wrestlers, although weight cutting in wrestling is a common practice at this age level.

CHAPTER II

METHODS OF PROCEDURE

Reported in this chapter is information relating to the subjects of the study--the experimental and control groups, the conditioning program to which the groups were subjected, and the method of administration of the selected strength tests.

Subjects

Originally, the nineteen wrestlers who participated as members of the Fossion High School Varsity Wrestling Team were to be used as subjects for this study. The final sample consisted of eight subjects (Table 1, page 13) who participated throughout the season in all the testing periods. The other subjects were dropped from the sampling due to absences from the testing periods, academic ineligibility or failure to remain in the wrestling program.

Experimental Group

The eight subjects in this study were required to control their weight to maintain eligibility for the weight class that they entered for the first meet of the season. The subjects were not required to lose

TABLE 1

SUBJECTS' WEIGHT DISTRIBUTION, AGE AND RECOMMENDED MINIMUM WEIGHT THROUGHOUT THE TESTING PERIOD

Subject	Age	Normal Weight T_1	Recommended Minimum Weight	Weight T_2	Weight T_3	Weight T_4
1	15	98	95	95	97	103
2	15	104	95	102	103	108
3	16	138	133	139	140	148
4	16	140	138	139	142	145
5	18	150	145	148	152	158
6	17	153	154	155	157	161
7	16	166	165	163	160	168
8	15	170	154	168	171	179

Normal Weight T_1--Weight at which the subject begins the season and weight at which the first test was administered.

Recommended Minimum weight--The minimum weight at which the doctor prescribes that the subject may wrestle.

Weight T_2--Weight of the subject at the time of test two, after four weeks of conditioning and wrestling competition.

Weight T_3--Weight of the subject at the time of test three, after ten weeks of wrestling training and competition.

Weight T_4--Weight of the subject at the time of test four, eight weeks after termination of the wrestling season.

excessive weight but were asked to maintain their weight within the limits of the Minnesota State Wrestling

Regulations which gives each weight class two pounds the first of January and one pound the first of February, thus allowing three pounds for normal growth during the wrestling season. The subjects were given a pre-season test, two mid-season tests and a post-season test eight weeks after termination of the wrestling season. The total testing period consisted of twenty-three weeks. The first mid-season test was conducted after four weeks of wrestling, and the second mid-season test was given after ten weeks of wrestling. The experimental period lasted for fifteen weeks during the wrestling season and for eight post-season weeks.

Control Group

The controls for this study are the results of the pre-season tests given the eight subjects in the experimental group.

Conditioning

The conditioning program utilized for the wrestlers of this study consisted of warm-up, stretching exercises, regular wrestling maneuvers, and of what the writer refers to as exercises of "maximum continuous movement". The warm-up and stretching exercises were of the following nature:

1. Jumping jack.
2. Trunk twister.
3. Trunk bender.

4. Squat thrust.

5. Push-up.

6. Sit-up.

7. Leg stretcher.

8. Wrestlers' bridge.

The wrestling maneuvers consisted of working on wrestling drills and scrimmaging. To utilize maximum continuous movement, the subjects were required to perform the following exercises as fast and as hard as they could, as suggested by the coach:

1. Studder step.

2. Jumping jack.

3. Squat thrust.

4. Push-up.

5. Sit-up.

6. Selected wrestling maneuvers.

   A. Sit out.

   B. Stand up.

   C. Switch.

The timed periods were three two-minute periods with twenty seconds rest between periods for the first week--the same total time as for a match. The second and third week periods consisted of two four-minute periods with twenty second rests between periods. The fourth and fifth weeks there were two six-minute periods with thirty second rests between periods. During the

remainder of the season the periods were ten to twelve minutes long with no rest periods. The "maximum continuous movement" was an exhaustive type of conditioning.

Strength Tests and the Administration of Such Tests

Shoulder Strength

The strength of the shoulder was measured by the number of shoulder bar dips which the subject could do on the parallel bars. The subject was required to start after he had mounted the bars to a locked (straight-arm) elbow position. The subject was then required to touch his shoulder to the bars and return to the locked elbow position. Each repetition was counted as one. No fraction or part of an uncompleted dip was regarded as work done. Each dip was considered as a unit of strength as related to weight, because the subject had moved his total weight each time a shoulder dip was executed.

Elbow Flexor Strength

Elbow flexor strength was measured by the use of a cable tensiometer. The subject was positioned in a sitting position on the floor, perpendicular to the test bench, with the side of the body to be tested snug to the test bench, thus eliminating any use of the legs or the other arm. The forearm was positioned at an 80 degree angle to the bench face. The subject was instructed to flex his elbow, putting tension on

a cable which had been connected to a strap which was placed around the forearm, midway between the wrist and elbow. The dial readings were then recorded and converted into pounds by use of the calibration chart accompanying the tensiometer. Both the right and the left elbow flexors were tested.

Leg Lift Strength

Leg lift strength was measured by using a leg dynamometer with a six-inch wide belt around the subject's waist, both ends of which were fastened to the test bar. The subject had the belt placed as low as possible over the hips and gluteal muscles. The subject was allowed to hold the test bar with both hands, both palms down. The dynamometer was suspended and fastened to a hook on the platform by means of an adjustable chain.

The subject was instructed to stand with his feet on the platform, and slightly toed out; the knees were bent no more than 120 degrees. The subject was instructed to keep his arms and back straight, head erect and chest up. Maximum leg lifts were then requested. The leg lift test was repeated three times each test period, and the best score was recorded. The scores were recorded in pounds as calibrated on the dynamometer.

Back Lift Strength

Back strength was measured by the use of the

same dynamometer. The subject held the bar with both hands, both palms down; the back was straight, knee and arm joints were locked and straight, the head was held erect and the chest out. The subject was required to bend at the waist at an angle of not more than 150 degrees to the floor, at which angle the dynamometer was affixed. The subject was then instructed to be sure to keep his arms and knees locked and to exert his maximal lift with his back. The test scores were then recorded in pounds as calibrated on the dynamometer.

Interpretation of Scores

The results of the arm flexion, back lift, and leg lift were recorded in pounds. The shoulder dips were recorded in units on the assumption that the subject had raised his total body weight every time he completed a shoulder dip. The total strength in pounds of the other tests were then divided by the total weight of the individual at the time of the test. This gave final answers of Unit Strength as related to weight.

CHAPTER III

RESULTS

Method of Analysis

The data that were collected from the eight subjects during the four tests were analyzed statistically to determine whether the strength changes that occurred from test period to test period were significant as related to weight changes. Unit Strength was used to relate strength to weight. Unit Strength was determined by dividing the strength recorded in pounds for each respective test by the weight of the subject at the time of the test. For example, for test II, if one of the subjects weighed 110 pounds and the strength recorded for the right arm flexor were 110 pounds, the Unit Strength would be: $\frac{110}{110}$ = Unit Strength of 1.

Statistical Procedure

The "t" technique[16] for testing the significance of the difference between means derived from correlated scores from small samples was used for this study. This

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[16]Quinn McNemar, Psychological Statistics (New York: John Wiley and Sons, Inc., 1949), p. 225.

test determines the ratio between the mean difference and the estimate of sampling error of the mean difference. The ratio was expressed as "t" and was certified for significance in a "t" table listed by McNemar[17] in his book, Psychological Statistics. The value of "t" is proportional to the degrees of freedom (N-1) allowed in determining the relationship between the mean difference and the estimate of sampling error of the mean difference.

For this study the 0.05 level of significance was selected as the criterion for significance. Complete data and the mathematical procedure utilized in the statistical analysis are presented in Appendix B, page 40.

Analysis of Results

Back Lift

In comparing the results of the pre-season test (test I) with those of the four week test (test II) on the back lift, a mean difference of Unit Strength was obtained. The mean difference was 0.155, the estimate of sampling error of the difference was 0.118, and the "t" value was 1.312 which was not significant at the 0.05 level of significance with seven degrees of freedom.

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[17] Ibid., p. 353.

TABLE 2

TEST COMPARISON OF BACK UNIT STRENGTH

Test Comparison	Subjects	Test	Retest	$S_{\bar{D}}$	$\bar{D}$	"t"	Signif. at 0.05 level
I to II (4 wks.)	8	13.684	14.928	0.104	0.155	1.312	no
I to III (10 wks.)	8	13.684	16.313	0.118	0.328	2.779	yes
I to IV (23 wks.)	8	13.684	17.312	0.112	0.453	4.044	yes
III to IV (8 post-season wks.)	8	16.313	17.312	0.104	0.124	1.191	no

$S_{\bar{D}}$ = Estimate of sampling error

$\bar{D}$ = Mean difference

"t" = "t" value, which is the ratio between the mean difference and the estimate of sampling error of the mean difference.

When comparing the results of the pre-season test (test I) with those of the ten week test (test III), the mean difference was 0.328, and the estimate of sampling error of the difference was 0.118. The "t" value was 2.779, which was significant at the 0.05 level of significance with seven degrees of freedom.

In comparing the results of the pre-season test (test I) with those of the post-season test (test IV), a mean difference of 0.453 was obtained. The estimate

of sampling error of the difference was 0.112 and the "t" value was 4.044 which was significant at the 0.05 level of significance with seven degrees of freedom.

The comparison of the results of the ten week test (test III) with those of the post-season test (test IV) revealed a mean difference of 0.124. The estimate of sampling error of the difference was 0.104. The "t" value was 1.191, which was not significant at the 0.05 level of significance with seven degrees of freedom. (See Table 2, page 21, and Appendix B, page 40.)

Leg Lift

In comparing the results of the pre-season test (test I) with those of the four week test (test II) of the leg lift, a mean difference of Unit Strength was obtained. The mean difference was 1.492, the estimate of sampling error of the difference was 0.859, and the "t" value of 1.740 was not significant at the 0.05 level of significance with seven degrees of freedom.

The comparison of the results of the pre-season test (test I) with those of the ten week test (test III) revealed a mean difference of 1.967. The estimate of sampling error of the mean difference was 0.612. The "t" value was 3.214 which was significant at the 0.05 level of significance with seven degrees of freedom.

In comparing the results of the four week test

(test I) with those of the post-season test (test IV), the mean difference was found to be 2.085 and the estimate of sampling error of the difference was 0.396. The "t" value was 5.265 which was significant at the 0.05 level of significance with seven degrees of freedom.

TABLE 3

TEST COMPARISON OF LEG LIFT UNIT STRENGTH

Test Comparison	Subjects	Test	Retest	$S_{\bar{D}}$	$\bar{D}$	"t"	Signif. at 0.05 level
I to II (4 wks.)	8	41.246	53.185	0.859	1.492	1.740	no
I to III (10 wks.)	8	41.246	56.981	0.612	1.967	3.214	yes
I to IV (23 wks.)	8	41.246	57.926	0.396	2.085	5.265	yes
III to IV (8 post-season wks.)	8	56.981	57.926	0.798	0.118	0.015	no

When comparing the results of the ten week test (test III) with those of the post-season test (test IV), a mean difference of 0.118 was obtained. The estimate of sampling error of the mean difference was 0.798, and the "t" value was 0.015 which was not significant at the 0.05 level of significance with seven degrees of freedom. (See Table 3, above, and Appendix B, page 40.)

Shoulder Bar Dip

In comparing the results of the pre-season test (test I) with those of the four week test (test II) of the shoulder bar dip, a mean difference of 1.375 was found. The estimate of sampling error of the mean difference was 0.564. The "t" value was 2.433 which was significant at the 0.05 level of significance with seven degrees of freedom.

TABLE 4

TEST COMPARISON OF SHOULDER BAR DIP UNIT STRENGTH

Test Comparison	Subjects	Test	Retest	$S_{\bar{D}}$	$\bar{D}$	"t"	Signif. at 0.05 level
I to II (4 wks.)	8	72	83	0.564	1.375	2.433	yes
I to III (10 wks.)	8	72	85	0.419	1.625	3.869	yes
I to IV (23 wks.)	8	72	83	0.777	1.375	1.767	no
III to IV (8 post-season wks.)	8	85	83	0.818	-0.250	-0.305	no

When comparing the results of the pre-season test (test I) with those of the ten week test (test III), a mean difference of 1.625 Unit Strength was obtained. The estimate of sampling error of the mean difference was 0.419. The "t" value was 3.869 which was significant

at the 0.05 level of significance with seven degrees of freedom.

In comparing the results of the pre-season test (test I) with those of the post-season test (test IV), a mean difference of 1.375 was obtained. The estimate of sampling error of the mean difference was 0.777. The "t" value was 1.767 which was not significant at the 0.05 level of significance with seven degrees freedom.

The comparison of the results of the ten week test (test III) with those of the post-season test (test IV) revealed a mean difference of minus 0.250. The estimate of sampling error of the mean difference was 0.818. The "t" value was minus 0.305 which was not significant at the 0.05 level of significance with seven degrees freedom. (See Table 4, page 24, and Appendix B, page 40.)

Arm Flexors

In comparing the results of the pre-season test (test I) with those of the four week test (test II) for the arm flexors, mean differences in Unit Strength were obtained. The mean difference for the left arm was 0.227, and estimate of sampling error of the mean difference was 0.074. The mean difference for the right arm was 0.354 and the estimate of sampling error of the mean difference was 0.105. The "t" value for the left

arm was 3.678, and for the right arm was 3.371. The "t" values for both right and left arms were significant at the 0.05 level with seven degrees freedom.

TABLE 5

TEST COMPARISON OF ARM FLEXOR UNIT STRENGTH

Test Comparison	Subjects	Test	Retest	$S_{\bar{D}}$	$\bar{D}$	"t"	Signif. at 0.05 level
I to II (4 wks.)							
Left	8	10.273	12.086	0.079	0.227	3.678	yes
Right	8	10.866	13.653	0.105	0.354	3.371	yes
I to III (10 wks.)							
Left	8	10.273	13.156	0.078	0.360	4.615	yes
Right	8	10.866	12.666	0.123	0.225	0.817	yes
I to IV (23 wks.)							
Left	8	10.273	14.328	0.082	0.501	6.104	no
Right	8	10.866	15.833	0.098	0.620	6.294	yes
III to IV (8 post-season wks.)							
Left	8	13.156	14.328	0.080	0.146	1.825	no
Right	8	12.666	15.833	0.177	0.395	2.231	no

When comparing the results of the pre-season test (test I) with those of the ten week test (test III), a mean difference was found for the left arm of 0.360 Unit Strength, and the estimate of sampling error of

the mean difference was 0.078. The mean difference for the right arm was 0.225 and the estimate of sampling error of the mean difference was 0.123. The "t" value for the left arm was 4.615 and for the right arm was 1.817, which at the 0.05 level of significance was significant for the left arm but was not significant for the right arm with seven degrees freedom.

In comparing the results of the pre-season test (test I) with those of the post-season test (test IV), a mean difference for the left arm of 0.501 was obtained, and estimate of sampling error of the mean difference was 0.082. The mean difference for the right arm was 0.620 and the estimate of sampling error of the mean difference was 0.098. The "t" value for the left arm was 6.109, and for the right arm 6.294 which was significant for both arms at the 0.05 level of significance. with seven degrees freedom.

The comparison of the results of the ten week test (test III) with those of the post-season test (test IV) revealed a mean difference for the left arm of 0.146. The estimate of sampling error of the mean difference was 0.080. The mean difference for the right arm was 0.395 and the estimate of sampling error of the mean difference was 0.177. The "t" value for the left arm was 1.825 and for the right arm was 2.231 which was not significant for either arm at the 0.05 level

of significance with seven degrees freedom. (See Table 5, page 26, and Appendix B, page 40.)

Unit Strength increase was shown to be significant in the elbow flexors and shoulders after four weeks of wrestling training. After ten weeks of wrestling training all four strength tests showed a significant increase except the right elbow flexor.

Post-season test results (test IV) compared to pre-season test results (test I) showed a significant increase of Unit Strength in all strength tests except the shoulder bar dip test. The comparison of the results of the ten week test (test III) with the results of the post-season test (test IV) showed an insignificant increase in all of the strength tests except the shoulders which showed an insignificant decrease in strength. Overall test results showed a definite increase in Unit Strength while participating in wrestling activity.

CHAPTER IV

DISCUSSION

The results of this study showed that a gradual gain in unit strength during the course of the wrestling season was the general trend. The shoulder, right and left elbow flexors were the muscle groups to exhibit a significant gain in unit strength after four weeks of wrestling conditioning. All other muscle groups gained in unit strength, but the gains were not significant. The elbow flexor and shoulder groups began to become stronger before other muscle groups probably because these are the muscles used the most, especially during the sustained contraction of practice scrimmage and wrestling competition.

Later in the test series, the results showed that the right elbow flexor seemed to be the only muscle group to lose unit strength. Upon closer observation it may be noted that this result was due to a strength reduction not in all the subjects, but in only two. One of these subjects (subject three) had complained of injury to the right arm shortly before the testing period. The other subject had sustained a right-side rib injury one week prior to test III. This probably caused the

right elbow flexor in this case to be less powerful than it might otherwise have been. If these individual injuries had not occurred, the right elbow flexor unit strength gain at this period would probably have correlated better with that of the other muscle groups.

Shoulder strength varied somewhat from the pattern of general strength increases exhibited by the other muscle groups in this study. Instead of gaining in strength during the eight post-season weeks as did the other groups, the shoulder appeared to decrease in strength from the end of the season to the eighth post-season week. Polo[18] found in his study that shoulder muscles gained in strength during six post-season weeks in college wrestlers.

The general strength decrease was found to be primarily the result of one subject's decrease in shoulder strength to below the level of the pre-season test. Several of the other subjects, however, also did not show strength gains after the conditioning program had ceased. The reason for these decreases is a matter for conjecture and further study. It is possible that shoulder muscles in growing boys need special conditioning exercises in order to exhibit strength gains.

The other post-season strength increases found in this study are in agreement with the work of Hassman[19]

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[18]Polo, op. cit.

[19]Hassman, op. cit.

and Polo[20] who both studied college wrestlers. When the strength increases are correlated with post-season weight gains, and unit strength gains tabulated, however, the post-season unit strength gains were found to be insignificant compared to the unit strength gains occurring while the subjects were engaged in strenuous physical conditioning. Hassman also found this to be true. It appears, therefore, that physical conditioning plays an important role in strength gain during the course of the wrestling season.

Yeager and Taylor[21] have shown that semi-starvation in growing animals is detrimental to the normal growth pattern of epiphyseal cartilage. Acheson[22] has found that short periods of starvation caused an abrupt slowing of skeletal growth in immature rats. Gillum,[23] Bryam[24] and Tuttle,[25] in separate studies, have reported no strength loss with weight cutting in college wrestlers during the wrestling season. No

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[20]Polo, op. cit.

[21]Interview with Vernon L. Yeager and John J. Taylor, Anatomy Department, University of North Dakota, July, 1966.

[22]Roy M. Acheson, "Effects of Starvation, Septicaemia and Chronic Illness on the Growth Cartilage Plate and Metaphysis of the Immature Rat," The Journal of Anatomy, III (January, 1959), pp. 123-130.

[23]Gillum, op. cit.

[24]Bryam, op. cit.

[25]Tuttle, op. cit.

comparative studies have been found which deal with high school wrestlers. Since high school boys are still growing and since there is no proof that weight cutting is not harmful to growing boys, it is this writer's opinion that a program of mandatory weight loss at this age level must be undertaken with extreme caution.

Several uncontrollable factors were found to be influential in affecting the results of this study. The subjects' home environments could have had a bearing on the results of testing. In at least one case reported in this study, the subject did not eat properly nor rest properly during the post-season test period.

It is not known what influence, if any, the subjects' differing levels of physical maturity had upon test results.

It is not known whether subjects were always feeling well physically during testing. At least one subject missed school because of illness between test periods.

Injury would definitely affect test results and the results have been evaluated as much as possible with this fact in mind.

The results of this study show that good strength gains are possible while wrestlers are engaged in physical conditioning and are making moderate weight gains throughout the season.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this investigation was to relate selected strength tests to weight changes of the high school varsity wrestler. Specific strength tests were the back lift, leg lift, shoulder bar dip, and elbow flexion. These measurements were made at selected time intervals to determine whether or not any strength or weight changes may have occurred during the course of the competitive and post-season periods.

The dynamometer was the instrument used to measure back and leg strength. The cable tensiometer was the instrument used to measure the strength of elbow flexion. Shoulder strength was measured by performing bar dips on the parallel bars.

Data were collected from eight members of the 1966 Fossten High School Varsity wrestling team by testing them four separate times--three times during the competitive season and once again eight weeks after the end of the competitive season and organized team training.

Upon completion of each testing period the raw

score in pounds was converted into Unit Strength by dividing the recorded strength in pounds by the weight of the individual.

The Unit Strength changes were illustrated by tables, and the data were analyzed to determine whether significant Unit Strength changes had occurred between test periods.

It was found that Unit Strength does significantly increase during the competitive season. After four weeks of training, all tests showed Unit Strength increases, but the elbow flexion and shoulder tests were the only ones to show a significant increase at this time. At ten weeks of training, all muscle groups showed a significant increase in strength except the right elbow flexor. When comparing the post-season tests to the pre-season tests, significant increases in Unit Strength were evident in all except the shoulder bar dip test. The shoulder muscles, however, had increased significantly in strength after four and ten weeks of wrestling training.

Unit Strength scores were highest on the post-season test, but when these scores were compared with weight gain, the strength increases after termination of wrestling conditioning and activity were found to be insignificant.

Conclusions

On the basis of the findings of this study the

following conclusions were drawn:

1. Significant Unit Strength increases were evident for each muscle group tested during the competitive wrestling season.
2. When accompanied by adequate physical conditioning, strength gain is not dependent upon weight changes within moderate limits.
3. A High School wrestler can increase strength pound for pound when allowed to maintain actual normal weight, or if allowed to gain moderately within limits imposed by Minnesota High School regulations.
4. A coach has no justification in cutting the weight of a maturing boy unless it can be proven that normal growth and development are not hindered.

Recommendations

It is suggested that in any future study of this nature, the following recommendations may be of value:

1. The use of a control group of non-wrestlers would help to determine whether the investigative findings are only characteristic of wrestlers or whether they are also true of other segments of the population.
2. Comparison of wrestlers' weight gains with

those of a control group would help to tell whether or not the wrestling group was allowed to gain weight normally.

3. A similar study encompassing a larger group or several different groups of High School wrestlers with more variation in weight changes should be undertaken.
4. An investigation of bone development as a measurement of physical maturity and as a barometer of skeletal maturation during the wrestling season should be done in conjunction with a study similar to this. X-rays of the wrist could probably be used effectively.

TABLES OF RAW TEST SCORES AND
CORRESPONDING UNIT STRENGTH

Subject	Test	Wt.	Shoulder Dip	Elbow Flexor Right	Elbow Flexor Left	Back	Leg
1	1	98	12	110(1.333)	110(1.333)	120(1.224)	410(4.185)
1	2	95	13	185(1.926)	165(1.737)	130(1.263)	580(5.105)
1	3	97	14	150(1.546)	160(1.649)	205(2.113)	650(6.701)
1	4	103	18	190(1.845)	165(1.602)	200(1.951)	520(5.048)
2	1	104	16	146(1.404)	150(1.442)	180(1.731)	570(5.481)
2	2	102	16	190(1.863)	165(1.618)	190(1.863)	710(6.961)
2	3	103	14	193(1.874)	176(1.718)	190(1.845)	715(6.942)
2	4	108	14	183(1.694)	190(1.759)	210(1.944)	755(6.991)
3	1	138	12	216(1.655)	190(1.377)	280(2.029)	740(5.362)
3	2	139	12	315(2.266)	256(1.842)	325(2.338)	1000(7.245)
3	3	140	12	260(1.857)	288(2.057)	300(2.143)	800(5.715)
3	4	148	12	375(2.554)	325(2.196)	310(2.095)	1125(7.601)
4	1	140	10	204(1.457)	236(1.686)	800(2.143)	840(6.000)
4	2	139	12	256(1.841)	224(1.612)	320(2.302)	1150(8.273)
4	3	142	12	253(1.782)	270(1.901)	315(2.218)	1350(9.507)
4	4	145	11	290(2.000)	257(1.772)	335(2.310)	1090(7.448)

Unit Strength in parentheses

TABLES OF RAW TEST SCORES AND
CORRESPONDING UNIT STRENGTH -- Continued

Subject	Test	Wt.	Shoulder Dip	Elbow Flexor Right	Elbow Flexor Left	Back	Leg
5	1	150	15	190(1.267)	160(1.600)	240(1.600)	995(5.967)
5	2	148	16	252(1.703)	216(1.466)	275(1.858)	1250(8.446)
5	3	152	16	288(1.895)	232(1.526)	370(2.434)	1300(8.553)
5	4	158	16	335(2.120)	270(1.735)	340(2.152)	1600(10.126)
6	1	153	8	186(1.216)	160(1.046)	210(1.372)	770(5.033)
6	2	155	9	212(1.368)	196(1.264)	220(1.419)	810(5.226)
6	3	157	10	236(1.503)	232(1.478)	295(1.879)	845(5.382)
6	4	161	8	315(1.957)	310(1.925)	350(2.174)	1190(7.391)
7	1	166	4	260(1.560)	240(1.446)	395(2.379)	920(5.542)
7	2	163	5	236(1.448)	224(1.374)	415(2.546)	1210(7.405)
7	3	160	7	250(1.563)	250(1.563)	355(2.219)	1600(10.00)
7	4	168	3	400(2.381)	347(2.065)	440(2.619)	1450(8.639)
8	1	170	0	200(1.176)	183(1.076)	205(1.206)	625(3.676)
8	2	168	0	208(1.238)	197(1.173)	225(1.339)	760(4.524)
8	3	171	0	232(1.357)	216(1.264)	250(1.462)	715(4.181)
8	4	179	1	233(1.302)	228(1.274)	370(2.067)	840(4.862)

TEST AND RETEST OF BACK
COMPARISON OF TESTS I AND II

Subject	T_1	T_2	D	D^2
1	1.224	1.263	0.039	1.548
2	1.731	1.863	0.132	0.017
3	2.029	2.338	0.309	0.095
4	2.143	2.302	0.159	0.026
5	1.600	1.858	0.258	0.067
6	1.372	1.419	0.047	0.002
7	2.379	2.546	0.167	0.028
8	1.206	1.339	0.133	0.018
	13.684	14.928	1.244	1.801

T = Test number

D = Difference

D^2 = Difference squared

Mean score of initial test = 13.684

Mean score of test II = 14.928

Sum of difference = 1.244

Sum of difference squared = 1.801

THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS DERIVED FROM CORRELATED SCORES FROM SMALL SAMPLES

Test I Compared to Test II Back Lift

$N = 8$

$\Sigma D = 1.244$

$\Sigma D^2 = 1.801$

$S_{\bar{D}}$ (estimate of sampling error of $\bar{D}$ $= \frac{S_D}{\sqrt{N}} =$

$$\frac{\sqrt{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}}{N - 1} \qquad \frac{\sqrt{1.801 - \frac{(1.244)^2}{8}}}{7}$$

$\sqrt{N}$ $\sqrt{8}$

$S_{\bar{D}} = .104$

$\bar{D}$ (Mean Difference $\frac{\Sigma D}{N} = \frac{1.244}{8} = .155$

$t = \frac{\bar{D}}{S_{\bar{D}}} = \frac{.155}{.104} = 1.490$

$df = N - 1 = 7$

"t" at .05 level = 2.365

Not significant at the .05 level.

TEST AND RETEST OF BACK
COMPARISON OF TESTS I AND III

Subject	T_1	T_3	D	D^2
1	1.224	2.113	0.889	0.790
2	1.731	1.845	0.114	0.013
3	2.029	2.143	0.114	0.013
4	2.143	2.218	0.075	0.006
5	1.600	2.434	0.834	0.696
6	1.372	1.879	0.507	0.257
7	2.379	2.219	-0.160	0.026
8	1.206	1.462	0.265	0.067
	13.864	16.313	2.629	1.868

T = Test number

D = Difference

D^2 = Difference squared

Mean score of initial test = 13.684

Mean score of test III = 16.313

Sum of difference = 2.629

Sum of difference squared = 1.868

THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS DERIVED FROM CORRELATED SCORES FROM SMALL SAMPLES

Test I Compared to Test III Back Lift

$N = 8$

$\Sigma D = 2.629$

$\Sigma D^2 = 1.868$

$S_{\bar{D}}$ (estimate of sampling error of $\bar{D}$ $= \dfrac{S_D}{\sqrt{N}} =$

$$\frac{\sqrt{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}}{N - 1} \qquad \frac{\sqrt{1.868 - \frac{(2.629)^2}{8}}}{7}$$

$$\frac{}{\sqrt{N}} \qquad \frac{}{\sqrt{8}}$$

$S_{\bar{D}} = .118$

$\bar{D}$ (Mean Difference $\dfrac{\Sigma D}{N} = \dfrac{2.629}{8} = .328$

$t = \dfrac{\bar{D}}{S_{\bar{D}}} = \dfrac{.328}{.118} = 2.779$

$df = N - 1 = 7$

"t" at .05 level = 2.365

Significant at the .05 level.

TEST AND RETEST OF BACK
COMPARISON OF TESTS I AND IV

Subject	T_1	T_4	D	D^2
1	1.224	1.951	0.727	0.529
2	1.731	1.944	0.213	0.045
3	2.029	2.095	0.066	0.004
4	2.143	2.310	0.167	0.028
5	1.600	2.152	0.552	0.305
6	1.372	2.174	0.802	0.643
7	2.379	2.619	0.040	0.058
8	1.206	2.067	0.861	0.741
	13.684	17.312	3.628	2.353

T = Test number

D = Difference

D^2 = Difference squared

Mean score of initial test = 13.684

Mean score of test IV = 17.312

Sum of difference = 3.628

Sum of difference squared = 2.353

THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS DERIVED FROM CORRELATED SCORES FROM SMALL SAMPLES

Test I Compared to Test IV — Back Lift

$N = 8$

$\Sigma D = 3.628$

$\Sigma D^2 = 2.353$

$S_{\bar{D}}$ (estimate of sampling error of $\bar{D}$ $= \frac{S_D}{\sqrt{N}} =$

$$\frac{\sqrt{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}}{N-1} \qquad \frac{\sqrt{2.353 - \frac{(3.628)^2}{8}}}{7}$$

$$\frac{}{\sqrt{N}} \qquad \frac{}{\sqrt{8}}$$

$S_{\bar{D}} = .112$

$\bar{D}$ (Mean Difference $\frac{\Sigma D}{N} = \frac{3.628}{8} = .453$

$t = \frac{\bar{D}}{S_{\bar{D}}} = \frac{.453}{.112} = 4.044$

$df = N - 1 = 7$

"t" at .05 level = 2.365

Significant at .05 level

TEST AND RETEST OF BACK
COMPARISON OF TESTS III AND IV

Subject	T_3	T_4	D	D^2
1	2.113	1.951	-0.162	0.026
2	1.845	1.944	0.099	0.009
3	2.143	2.095	-0.048	0.002
4	2.218	2.310	0.092	0.008
5	2.434	2.152	-0.282	0.079
6	1.879	2.174	0.295	0.116
7	2.219	2.619	0.400	0.160
8	1.462	2.067	0.605	0.366
	16.313	17.312	0.999	0.769

T = Test number

D = Difference

D^2 = Difference squared

Mean score of test III = 16.313

Mean score of test IV = 17.312

Sum of difference = 0.999

Sum of difference squared = 0.769

THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS
DERIVED FROM CORRELATED SCORES FROM SMALL SAMPLES

Test III Compared to Test IV Back Lift

$N = 8$

$\Sigma D = .999$

$\Sigma D^2 = .769$

$S_{\bar{D}}$ (estimate of sampling error of $\bar{D}$ $= \frac{S_D}{\sqrt{N}} =$

$$\frac{\sqrt{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}}{N - 1} \qquad \frac{\sqrt{.769 - \frac{(.999)^2}{8}}}{7}$$

$$\frac{}{\sqrt{N}} \qquad \frac{}{\sqrt{8}}$$

$S_{\bar{D}} = .104$

$\bar{D}$ (Mean Difference $\frac{\Sigma D}{N} = \frac{.999}{8} = .124$

$t = \frac{\bar{D}}{S_{\bar{D}}} = \frac{.124}{.104} = 1.191$

$df = N - 1 = 7$

"t" at .05 level = 2.365

Not significant at the .05 level.

TEST AND RETEST OF BACK RAW SCORE
COMPARISON OF TESTS III AND IV

Subject	T_3	T_4	D	D^2
1	205	200	-5	10
2	190	210	20	400
3	300	310	10	100
4	315	335	20	400
5	370	340	-30	900
6	295	350	55	3025
7	355	440	85	7225
8	250	370	120	14400
	2280	2555	225	26,460

T = Test number

D = Difference

D^2 = Difference squared

Mean score of test III = 2280

Mean score of test IV = 2555

Difference of mean score = 225

Difference squared = 26,460

THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS
DERIVED FROM CORRELATED SCORES FROM SMALL SAMPLES

Test III Compared to Test IV Back Lift (Raw Score)

$N = 8$

$\Sigma D = 225$

$\Sigma D^2 = 26{,}460$

$S_{\bar{D}}$ (estimate of sampling error of $\bar{D}$ $= \dfrac{S_D}{\sqrt{N}} =$

$$\frac{\sqrt{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}}{N-1} \qquad \frac{\sqrt{26{,}460 - \frac{(225)^2}{8}}}{7}$$

$$\frac{}{\sqrt{N}} \qquad \frac{}{\sqrt{8}}$$

$S_{\bar{D}} = 18.7$

$\bar{D}$ (Mean Difference $\dfrac{\Sigma D}{N} = \dfrac{225}{8} = 28.1$

$$t = \frac{\bar{D}}{S_{\bar{D}}} = \frac{28.1}{18.7} = 1.503$$

$df = N - 1 = 7$

"t" at .05 level = 2.365

Not significant at .05 level.

TEST AND RETEST OF LEG
COMPARISON OF TESTS I AND II

Subject	T_1	T_2	D	D^2
1	4.185	5.105	0.920	0.846
2	5.481	6.961	1.480	2.190
3	5.362	7.245	1.883	3.545
4	6.000	8.273	2.273	5.166
5	5.967	8.446	2.479	5.137
6	5.033	5.226	0.193	0.037
7	5.542	7.405	1.863	3.470
8	3.676	4.524	0.848	0.719
	41.246	53.185	11.939	22.114

T = Test number

D = Difference

D^2 = Difference squared

Mean score of initial test = 41.246

Mean score of test I = 53.185

Sum of difference = 11.939

Sum of difference squared = 22.114

THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS
DERIVED FROM CORRELATED SCORES FROM SMALL SAMPLES

Test I Compared to Test II Leg Lift

$N = 8$

$\Sigma D = 11.939$

$\Sigma D^2 = 22.114$

$S_{\bar{D}}$ (estimate of sampling error of $\bar{D} = \frac{S_D}{\sqrt{N}} =$

$$\sqrt{\frac{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}{N-1}} \qquad \sqrt{\frac{22.114 - \frac{(11.939)^2}{8}}{7}}$$

$$\sqrt{N} \qquad \sqrt{8}$$

$S_{\bar{D}} = .085$

$\bar{D}$ (Mean Difference $\frac{\Sigma D}{N} = \frac{11.939}{8} = 1.492$

$t = \frac{\bar{D}}{S_{\bar{D}}} = \frac{1.492}{.085} = 1.740$

$df = N - 1 = 7$

"t" at .05 level = 2.365

Not significant at the .05 level.

TEST AND RETEST OF LEG
COMPARISON OF TESTS I AND III

Subject	T_1	T_3	D	D^2
1	4.185	6.701	2.516	6.330
2	5.481	6.942	1.461	2.135
3	5.362	5.715	0.353	0.125
4	6.000	9.507	3.507	12.299
5	5.967	8.553	2.586	6.687
6	5.033	5.382	0.349	0.122
7	5.542	10.000	4.458	19.874
8	3.676	4.181	0.505	0.255
	41.246	56.981	15.735	47.827

T = Test number

D = Difference

D^2 = Difference squared

Mean score of initial test = 41.246

Mean score of test III = 56.981

Sum of difference = 15.735

Sum of difference squared = 47.827

THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS
DERIVED FROM CORRELATED SCORES FROM SMALL SAMPLES

Test I Compared to Test III — Leg Lift

$N = 8$

$\Sigma D = 15.735$

$\Sigma D^2 = 47.827$

$S_{\bar{D}}$ (estimate of sampling error of $\bar{D}$ $= \dfrac{S_D}{\sqrt{N}} =$

$$\frac{\sqrt{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}}{N-1} \qquad \frac{\sqrt{47.827 - \frac{(15.735)^2}{8}}}{7}$$

$$\sqrt{N} \qquad \sqrt{8}$$

$S_{\bar{D}} = .612$

$\bar{D}$ (Mean Difference $\dfrac{\Sigma D}{N} = \dfrac{15.735}{8} = 1.967$

$t = \dfrac{\bar{D}}{S_{\bar{D}}} = \dfrac{1.976}{.612} = 3.214$

$df = N - 1 = 7$

"t" at .05 level = 2.365

Significant at the .05 level.

TEST AND RETEST OF LEG
COMPARISON OF TESTS I AND IV

Subject	T_1	T_4	D	D^2
1	4.185	5.048	0.863	0.746
2	5.481	6.991	1.510	2.280
3	5.362	7.601	2.239	5.013
4	6.000	7.448	1.448	2.097
5	5.967	10.126	4.159	17.297
6	5.033	7.391	2.358	5.560
7	5.542	8.639	3.097	9.591
8	3.676	4.682	1.006	1.012
	41.246	57.926	16.680	43.596

T = Test number

D = Difference

D^2 = Difference squared

Mean score of initial test = 41.246

Mean score of test IV = 57.926

Sum of difference = 16.680

Sum of difference squared = 43.596

THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS DERIVED FROM CORRELATED SCORES FROM SMALL SAMPLES

Test I Compared to Test IV — Leg Lift

$N = 8$

$\Sigma D = 16.680$

$\Sigma D^2 = 43.596$

$S_{\bar{D}}$ (estimate of sampling error of $\bar{D}$ $= \frac{S_D}{\sqrt{N}} =$

$$\frac{\sqrt{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}}{N-1} \qquad \frac{\sqrt{43.596 - \frac{(16.680)^2}{8}}}{7}$$

$$\sqrt{N} \qquad \sqrt{8}$$

$S_{\bar{D}} = .396$

$\bar{D}$ (Mean Difference $\frac{\Sigma D}{N} = \frac{16.680}{8} = 2.085$

$t = \frac{\bar{D}}{S_{\bar{D}}} = \frac{2.085}{.396} = 5.265$

$df = N - 1 = 7$

"t" at .05 level = 2.365

Significant at .05 level.

TEST AND RETEST OF LEG
COMPARISON OF TESTS III AND IV

Subject	T_3	T_4	D	D^2
1	6.701	5.048	-1.653	2.732
2	6.942	6.991	0.049	0.002
3	5.715	7.601	1.886	3.557
4	9.507	7.448	-2.059	4.239
5	8.553	10.126	1.573	2.474
6	5.382	7.391	2.009	4.036
7	10.000	8.639	-1.361	1.852
8	4.181	4.682	0.501	0.251
	56.981	57.926	0.945	19.143

T = Test number

D = Difference

D^2 = Difference squared

Mean score of test III = 56.981

Mean score of test IV = 57.926

Sum of difference = 0.945

Sum of difference squared = 19.143

THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS
DERIVED FROM CORRELATED SCORES FROM SMALL SAMPLES

Test III Compared to Test IV Leg Lift

$N = 8$

$\Sigma D = .935$

$\Sigma D^2 = 19.143$

$S_{\bar{D}}$ (estimate of sampling error of $\bar{D}$ $= \frac{S_D}{\sqrt{N}} =$

$$\frac{\sqrt{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}}{N-1} \qquad \frac{\sqrt{19.143 - \frac{(.945)^2}{8}}}{7}$$

$\sqrt{N}$ $\sqrt{8}$

$S_{\bar{D}} = .798$

$\bar{D}$ (Mean Difference $\frac{\Sigma D}{N} = \frac{.945}{8} = .118$

$t = \frac{\bar{D}}{S_{\bar{D}}} = \frac{.118}{.798} = .015$

$df = N - 1 = 7$

"t" at .05 level = 2.365

Not significant at .05 level.

TEST AND RETEST OF LEG RAW SCORE
COMPARISON OF TESTS III AND IV

Subject	T_3	T_4	D	D^2
1	650	520	-130	16,900
2	715	755	40	1,600
3	800	1125	325	105,625
4	1350	1080	-270	72,900
5	1300	1600	300	90,000
6	845	1190	345	119,025
7	1600	1450	-150	22,500
8	715	840	125	15,625
	7975	8560	585	442,575

T = Test number

D = Difference

D^2 = Difference squared

Mean score of test III = 7.975

Mean score of test IV = 8,560

Difference of mean score = 585

Difference squared = 442,575

THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS
DERIVED FROM CORRELATED SCORES FROM SMALL SAMPLES

Test III Compared to Test IV Leg Lift (Raw Score)

$N = 8$

$\Sigma D = 585$

$\Sigma D^2 = 442,575$

$S_{\bar{D}}$ (estimate of sampling error of $\bar{D}$ $= \dfrac{S_D}{\sqrt{N}} =$

$$\frac{\sqrt{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}}{N-1} \qquad \frac{\sqrt{442,575 - \frac{(585)^2}{8}}}{7}$$

$$\frac{}{\sqrt{N}} \qquad \frac{}{\sqrt{8}}$$

$S_{\bar{D}} = 84.4$

$\bar{D}$ (Mean Difference $\dfrac{\Sigma D}{N} = \dfrac{585}{8} = 73$

$$t = \frac{\bar{D}}{S_{\bar{D}}} = \frac{73}{84.4} = .87$$

$df = N - 1 = 7$

"t" at .05 level = 2.365

Not significant at the .05 level.

TEST AND RETEST OF SHOULDER
COMPARISON OF TESTS I AND II

Subject	T_1	T_2	D	D^2
1	12	13	1	1
2	11	16	5	25
3	12	12	0	0
4	10	12	2	4
5	15	16	1	1
6	8	9	1	1
7	4	5	1	1
8	0	0	0	0
	72	83	11	33

T = Test number

D = Difference

D^2 = Difference squared

Mean score of initial test = 72

Mean score of test II = 83

Sum of difference = 11

Sum of difference squared = 33

THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS
DERIVED FROM CORRELATED SCORES FROM SMALL SAMPLES

Test I Compared to Test II Shoulder Bar Dip

$N = 8$

$\Sigma D = 11$

$\Sigma D^2 = 33$

$S_{\bar{D}}$ (estimate of sampling error of $\bar{D}$ $= \dfrac{S_D}{\sqrt{N}} =$

$$\sqrt{\frac{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}{N-1}} \qquad \sqrt{\frac{33 - \frac{(11)^2}{8}}{7}}$$

$$\sqrt{N} \qquad \sqrt{8}$$

$S_{\bar{D}} = .564$

$\bar{D}$ (Mean Difference $\dfrac{\Sigma D}{N} = \dfrac{11}{8} = 1.375$

$t = \dfrac{\bar{D}}{S_{\bar{D}}} = \dfrac{1.375}{.564} = 2.433$

$df = N - 1 = 7$

"t" at .05 level = 2.365

Significant at the .05 level.

TEST AND RETEST OF SHOULDER
COMPARISON OF TESTS I AND III

Subject	T_1	T_3	D	D^2
1	12	14	2	4
2	11	14	3	9
3	12	12	0	0
4	10	12	2	4
5	15	16	1	1
6	8	10	2	4
7	4	7	3	9
8	0	0	0	0
	72	85	13	31

T = Test number

D = Difference

D^2 = Difference squared

Mean score of initial test = 72

Mean score of test III = 85

Sum of difference = 13

Sum of difference squared = 31

THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS DERIVED FROM CORRELATED SCORES FROM SMALL SAMPLES

Test I Compared to Test III Shoulder Bar Dip

$N = 8$

$\Sigma D = 13$

$\Sigma D^2 = 31$

$S_{\bar{D}}$ (estimate of sampling error of $\bar{D} = \frac{S_D}{\sqrt{N}} =$

$$\sqrt{\frac{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}{N-1}} \qquad \sqrt{\frac{31 - \frac{(13)^2}{8}}{7}}$$

$$\sqrt{N} \qquad \sqrt{8}$$

$S_{\bar{D}} = .419$

$\bar{D}$ (Mean Difference $\frac{\Sigma D}{N} = \frac{13}{8} = 1.625$

$t = \frac{\bar{D}}{S_{\bar{D}}} = \frac{1.625}{.419} = 3.869$

$df = N - 1 = 7$

"t" at .05 level = 2.365

Significant at the .05 level.

TEST AND RETEST OF SHOULDER
COMPARISON OF TESTS I AND IV

Subject	T_1	T_4	D	D^2
1	12	18	6	36
2	11	14	3	9
3	12	12	0	0
4	10	11	1	1
5	15	16	1	1
6	8	8	0	0
7	4	3	-1	-1
8	0	1	1	1
	72	83	11	47

T = Test number

D = Difference

D^2 = Difference squared

Mean score of initial test = 72

Mean score of test IV = 83

Sum of difference = 11

Sum of difference squared = 47

THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS
DERIVED FROM CORRELATED SCORES FROM SMALL SAMPLES

Test I Compared to Test IV Shoulder Bar Dip

$N = 8$

$\Sigma D = 11$

$\Sigma D^2 = 47$

$S_{\overline{D}}$ (estimate of sampling error of $\overline{D} = \frac{S_D}{\sqrt{N}} =$

$$\sqrt{\frac{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}{N-1}} \qquad \sqrt{\frac{47 - \frac{(11)^2}{8}}{7}}$$

$$\sqrt{N} \qquad \sqrt{8}$$

$S_{\overline{D}} = .777$

$\overline{D}$ (Mean Difference $\frac{\Sigma D}{N} = \frac{11}{8} = 1.375$

$t = \frac{\overline{D}}{S_{\overline{D}}} = \frac{1.375}{.777} = 1.767$

$df = N - 1 = 7$

"t" at .05 level = 2.365

Not significant at the .05 level.

TEST AND RETEST OF SHOULDER
COMPARISON OF TESTS III AND IV

Subject	T_3	T_4	D	D^2
1	14	18	4	16
2	14	14	0	0
3	12	12	0	0
4	12	11	-1	1
5	16	16	0	0
6	10	8	-2	4
7	7	3	-4	16
8	0	1	1	1
	85	83	-2	38

T = Test number

D = Difference

D^2 = Difference squared

Mean score of test III = 85

Mean score of test IV = 83

Sum of difference = -2

Sum of difference squared = 38

THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS
DERIVED FROM CORRELATED SCORES FROM SMALL SAMPLES

Test III Compared to Test IV Shoulder Bar Dip

$N = 8$

$\Sigma D = -2$

$\Sigma D^2 = 38$

$S_{\bar{D}}$ (estimate of sampling error of $\bar{D}$ $= \dfrac{S_D}{\sqrt{N}} =$

$$\frac{\sqrt{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}}{N-1} \qquad \frac{\sqrt{38 - \frac{(-2)^2}{8}}}{7}$$

$$\frac{}{\sqrt{N}} \qquad \frac{}{\sqrt{8}}$$

$S_{\bar{D}} = .818$

$\bar{D}$ (Mean Difference $\dfrac{\Sigma D}{N} = \dfrac{-2}{8} = .250$

$$t = \frac{\bar{D}}{S_{\bar{D}}} = \frac{.250}{.818} = -.305$$

$df = N - 1 = 7$

"t" at .05 level = 2.365

Not significant at the .05 level.

TEST AND RETEST OF RIGHT ARM FLEXOR
COMPARISON OF TESTS I AND II

Subject	T_1	T_2	D	D^2
1	1.133	1.926	0.793	0.629
2	1.404	1.863	0.459	0.211
3	1.653	2.266	0.613	0.376
4	1.457	1.841	0.434	0.188
5	1.267	1.703	0.436	0.190
6	1.216	1.368	0.152	0.023
7	1.560	1.448	-0.112	0.013
8	1.176	1.238	0.062	0.001
	10.866	13.653	2.737	1.631

T = Test number

D = Difference

D^2 = Difference squared

Mean score of initial Test = 10.866

Mean score of Test II = 13.653

Sum of Difference = 2.737

Sum of Difference squared = 1.631

THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS
DERIVED FROM CORRELATED SCORES FROM SMALL SAMPLES

Test I Compared to Test II Right Arm Flexion

$N = 8$

$\Sigma D = 2.737$

$\Sigma D^2 = 1.631$

$S_{\bar{D}}$ (estimate of sampling error of $\bar{D}$ $= \dfrac{S_D}{\sqrt{N}} =$

$$\frac{\sqrt{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}}{N-1} \qquad \frac{\sqrt{1.631 - \frac{(2.737)^2}{8}}}{7}$$

$$\frac{}{\sqrt{N}} \qquad \frac{}{\sqrt{8}}$$

$S_{\bar{D}} = .105$

$\bar{D}$ (Mean Difference $\dfrac{\Sigma D}{N} = \dfrac{2.737}{8} = .342$

$$t = \frac{\bar{D}}{S_{\bar{D}}} = \frac{.348}{.105} = 3.215$$

$df = N - 1 = 7$

"t" at .05 level = 2.365

Significant at .05 level.

TEST AND RETEST OF RIGHT ARM FLEXOR
COMPARISON OF TESTS I AND III

Subject	T_1	T_3	D	D^2
1	1.133	1.546	0.413	0.171
2	1.404	1.874	0.470	0.221
3	1.653	1.146	-0.507	0.257
4	1.457	1.782	0.325	0.106
5	1.267	1.895	0.628	0.394
6	1.216	1.503	0.287	0.082
7	1.560	1.563	0.003	0.000
8	1.176	1.357	0.181	0.033
	10.866	12.666	1.800	1.264

T = Test number

D = Difference

D^2 = Difference squared

Mean score of initial test = 10.866

Mean score of Test III = 12.666

Sum of Difference = 1.800

Sum of Difference squared = 1.264

THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS DERIVED FROM CORRELATED SCORES FROM SMALL SAMPLES

Test I Compared to Test III Right Arm Flexion

$N = 8$

$\Sigma D = 1.800$

$\Sigma D^2 = 1.264$

$S_{\bar{D}}$ (estimate of sampling error of $\bar{D}$ $= \frac{S_D}{\sqrt{N}} =$

$$\sqrt{\frac{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}{N-1}} \qquad \sqrt{\frac{1.264 - \frac{(1.800)^2}{8}}{7}}$$

$$\sqrt{N} \qquad \sqrt{8}$$

$S_{\bar{D}} = .123$

$\bar{D}$ (Mean Difference $\frac{\Sigma D}{N} = \frac{1.800}{8} = .225$

$t = \frac{\bar{D}}{S_{\bar{D}}} = \frac{.225}{.123} = 1.817$

$df = N - 1 = 7$

"t" at .05 level = 2.365

Not significant at the .05 level.

TEST AND RETEST OF RIGHT ARM FLEXOR
COMPARISON OF TESTS I AND IV

Subject	T_1	T_4	D	D^2
1	1.133	1.845	0.712	0.507
2	1.404	1.694	0.290	0.084
3	1.653	1.534	0.881	0.776
4	1.457	2.000	0.543	0.295
5	1.267	2.120	0.853	0.728
6	1.186	1.957	0.741	0.549
7	1.560	2.381	0.821	0.674
8	1.176	1.302	0.126	0.016
	10.866	15.833	4.967	3.629

T = Test number

D = Difference

D^2 = Difference squared

Mean score of initial test = 10.866

Mean score of test IV = 15.833

Sum of difference = 4.967

Sum of difference squared = 3.629

THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS
DERIVED FROM CORRELATED SCORES FROM SMALL SAMPLES

Test I Compared to Test IV Right Arm Flexion

$N = 8$

$\Sigma D = 4.967$

$\Sigma D^2 = 3.629$

$S_{\bar{D}}$ (estimate of sampling error of $\bar{D} = \frac{S_D}{\sqrt{N}} =$

$$\frac{\sqrt{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}}{N-1} \qquad \frac{\sqrt{3.629 - \frac{(4.967)^2}{8}}}{7}$$

$$\frac{}{\sqrt{N}} \qquad \frac{}{\sqrt{8}}$$

$S_{\bar{D}} = .098$

$\bar{D}$ (Mean Difference $\frac{\Sigma D}{N} = \frac{4.967}{8} = .620$

$$t = \frac{\bar{D}}{S_{\bar{D}}} = \frac{.620}{.098} = 6.294$$

$df = N - 1 = 7$

"t" at .05 level = 2.365

Significant at .05 level.

TEST AND RETEST OF RIGHT ARM FLEXOR
COMPARISON OF TESTS III AND IV

Subject	T_3	T_4	D	D^2
1	1.546	1.845	0.299	0.089
2	1.874	1.694	-0.180	0.032
3	1.146	2.534	1.388	0.927
4	1.782	2.000	0.218	0.047
5	1.895	2.120	0.225	0.051
6	1.503	1.957	0.454	0.206
7	1.563	2.381	0.818	0.669
8	1.357	1.302	-0.055	0.003
	12.666	15.833	3.167	3.024

T = Test number

D = Difference

D^2 = Difference squared

Mean score of Test III = 12.666

Mean score of Test IV = 15.833

Sum of difference = 3.167

Sum of difference squared = 3.024

THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS DERIVED FROM CORRELATED SCORES FROM SMALL SAMPLES

Test III Compared to Test IV Right Arm Flexion

$N = 8$

$\Sigma D = 3.167$

$\Sigma D^2 = 3.024$

$S_{\overline{D}}$ (estimate of sampling error of $\overline{D}$ $= \frac{S_D}{\sqrt{N}} =$

$$\sqrt{\frac{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}{N-1}} \qquad \sqrt{\frac{3.024 - \frac{(3.167)^2}{8}}{7}}$$

$$\sqrt{N} \qquad \sqrt{8}$$

$S_{\overline{D}} = .177$

$\overline{D}$ (Mean Difference $\frac{\Sigma D}{N} = \frac{3.167}{8} = .395$

$t = \frac{\overline{D}}{S_{\overline{D}}} = \frac{.395}{.177} = 2.231$

$df = N - 1 = 7$

"t" at .05 level = 2.365

Not significant at the .05 level.

TEST AND RETEST OF RIGHT ARM RAW SCORE
COMPARISON OF TESTS III AND IV

Subject	T_3	T_4	D	D^2
1	150	190	40	160
2	193	183	-10	100
3	260	375	115	13,225
4	253	210	37	1,369
5	288	335	47	2,209
6	236	315	79	6,241
7	250	400	150	22,500
8	233	233	0	0
	1863	2321	458	45,804

T = Test number

D = Difference

D^2 = Difference squared

Mean score of Test III = 1863

Mean score of Test IV = 2321

Difference of mean score = 458

Difference squared = 45,804

THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS DERIVED FROM CORRELATED SCORES FROM SMALL SAMPLES

Test III Compared to Test IV — Right Arm Flexion (Raw Score)

$N = 8$

$\Sigma D = 458$

$\Sigma D^2 = 45{,}804$

$S_{\bar{D}}$ (estimate of sampling error of $\bar{D} = \frac{S_D}{\sqrt{N}} =$

$$\frac{\sqrt{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}}{N-1} \qquad \frac{\sqrt{45{,}804 - \frac{(458)^2}{8}}}{7}$$

$$\frac{}{\sqrt{N}} \qquad \frac{}{\sqrt{8}}$$

$S_{\bar{D}} = 21.5$

$\bar{D}$ (Mean Difference $\frac{\Sigma D}{N} = \frac{458}{8} = 57$

$$t = \frac{\bar{D}}{S_{\bar{D}}} = \frac{57}{21.5} = 2.657$$

$df = N - 1 = 7$

"t" at .05 level = 2.365

Significant at .05 level.

TEST AND RETEST OF LEFT ARM FLEXOR
COMPARISON OF TESTS I AND II

Subject	T_1	T_2	D	D^2
1	1.133	1.737	0.609	0.371
2	1.442	1.618	0.176	0.031
3	1.377	1.842	0.465	0.216
4	1.686	1.612	-0.074	0.005
5	1.067	1.466	0.399	0.159
6	1.046	1.264	0.218	0.048
7	1.446	1.374	-0.072	0.005
8	1.076	1.173	0.097	0.009
	10.273	12.068	1.818	0.844

T = Test number

D = Difference

D^2 = Difference squared

Mean score of initial test = 10.273

Mean score of Test II = 12.086

Sum of Difference = 1.818

Sum of Difference squared = 0.844

THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS
DERIVED FROM CORRELATED SCORES FROM SMALL SAMPLES

Test I Compared to Test II — Left Arm Flexion

$N = 8$

$\Sigma D = 1.818$

$\Sigma D^2 = .844$

$S_{\overline{D}}$ (estimate of sampling error of $\overline{D}$ $= \dfrac{S_D}{\sqrt{N}} =$

$$\frac{\sqrt{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}}{N-1} \qquad \frac{\sqrt{.844 - \frac{(1.818)^2}{8}}}{7}$$

$$\frac{}{\sqrt{N}} \qquad \frac{}{\sqrt{8}}$$

$S_{\overline{D}} = .079$

$\overline{D}$ (Mean Difference $\dfrac{\Sigma D}{N} = \dfrac{1.818}{8} = .227$

$$t = \frac{\overline{D}}{S_{\overline{D}}} = \frac{.227}{.079} = 3.678$$

$df = N - 1 = 7$

"t" at .05 level = 2.365

Significant at the .05 level.

TEST AND RETEST OF LEFT ARM FLEXOR
COMPARISON OF TESTS I AND III

Subject	T_1	T_3	D	D^2
1	1.133	1.644	0.516	0.266
2	1.442	1.718	0.276	0.076
3	1.377	2.057	0.680	0.462
4	1.686	1.901	0.215	0.046
5	1.067	1.526	0.459	0.211
6	1.046	1.478	0.432	0.187
7	1.446	1.563	0.117	0.014
8	1.076	1.264	0.188	0.035
	10.273	13.156	2.883	1.297

T = Test number

D = Difference

D^2 = Difference squared

Mean score of initial test = 10.273

Mean score of Test III = 13.156

Sum of Difference = 2.883

Sum of Difference squared = 1.297

THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS DERIVED FROM CORRELATED SCORES FROM SMALL SAMPLES

Test I Compared to Test III Left Arm Flexion

$N = 8$

$\Sigma D = 2.883$

$\Sigma D^2 = 1.297$

$S_{\bar{D}}$ (estimate of sampling error of $\bar{D}$ $= \frac{S_D}{\sqrt{N}} =$

$$\frac{\sqrt{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}}{N-1} \qquad \frac{\sqrt{1.297 - \frac{(2.883)^2}{8}}}{7}$$

$$\frac{}{\sqrt{N}} \qquad \frac{}{\sqrt{8}}$$

$S_{\bar{D}} = .078$

$\bar{D}$ (Mean Difference $\frac{\Sigma D}{N} = \frac{2.883}{8} = .360$

$t = \frac{\bar{D}}{S_{\bar{D}}} = \frac{.360}{.078} = 4.615$

$df = N - 1 = 7$

"t" at .05 level = 2.365

Significant at the .05 level.

TEST AND RETEST OF LEFT ARM FLEXOR
COMPARISON OF TESTS I AND IV

Subject	T_1	T_4	D	D^2
1	1.133	1.602	0.469	0.220
2	1.442	1.759	0.317	0.100
3	1.377	2.196	0.819	0.671
4	1.686	1.772	0.086	0.007
5	1.067	1.735	0.668	0.446
6	1.046	1.925	0.829	0.671
7	1.446	2.065	0.619	0.383
8	1.076	1.274	0.198	0.039
	10.273	14.328	4.005	2.527

T = Test number

D = Difference

D^2 = Difference squared

Mean score of initial test = 10.273

Mean score of Test IV = 14.328

Sum of Difference = 4.005

Sum of Difference squared = 2.527

THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS DERIVED FROM CORRELATED SCORES FROM SMALL SAMPLES

Test I Compared to Test IV Left Arm Flexion

$N = 8$

$\Sigma D = 4.005$

$\Sigma D^2 = 2.527$

$S_{\bar{D}}$ (estimate of sampling error of $\bar{D}$ $= \frac{S_D}{\sqrt{N}} =$

$$\sqrt{\frac{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}{N-1}} \qquad \sqrt{\frac{2.527 - \frac{(4.005)^2}{8}}{7}}$$

$$\sqrt{N} \qquad \sqrt{8}$$

$S_{\bar{D}} = .082$

$\bar{D}$ (Mean Difference $\frac{\Sigma D}{N} = \frac{4.005}{8} = .501$

$t = \frac{\bar{D}}{S_{\bar{D}}} = \frac{.501}{.082} = 6.109$

$df = N - 1 = 7$

"t" at .05 level = 2.365

Significant at the .05 level.

TEST AND RETEST OF LEFT ARM FLEXOR
COMPARISON OF TESTS III AND IV

Subject	T_3	T_4	D	D^2
1	1.649	1.602	-0.047	0.022
2	1.718	1.759	0.041	0.002
3	2.057	2.196	0.139	0.019
4	1.901	1.772	-0.129	0.017
5	1.526	1.735	0.209	0.044
6	1.478	1.925	0.447	0.200
7	1.563	2.065	0.502	0.252
8	1.563	1.274	0.010	0.000
	13.156	14.328	1.172	0.556

T = Test number

D = Difference

D^2 = Difference squared

Mean score of Test III = 13.156

Mean score of Test IV = 14.328

Sum of Difference = 1.172

Sum of Difference squared = 0.556

THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS
DERIVED FROM CORRELATED SCORES FROM SMALL SAMPLES

Test III Compared to Test IV Left Arm Flexion

$N = 8$

$\Sigma D = 1.172$

$\Sigma D^2 = .556$

$S_{\bar{D}}$ (estimate of sampling error of $\bar{D}$ $= \frac{S_D}{\sqrt{N}} =$

$$\sqrt{\frac{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}{N-1}} \qquad \sqrt{\frac{.556 - \frac{(1.172)^2}{8}}{7}}$$

$$\frac{}{\sqrt{N}} \qquad \frac{}{\sqrt{8}}$$

$S_{\bar{D}} = .080$

$\bar{D}$ (Mean Difference $\frac{\Sigma D}{N} = \frac{1.172}{8} = .146$

$t = \frac{\bar{D}}{S_{\bar{D}}} = \frac{.146}{.080} = 1.825$

$df = N - 1 = 7$

"t" at .05 level = 2.365

Not significant at the .05 level.

TEST AND RETEST OF LEFT ARM RAW SCORE
COMPARISON OF TESTS III AND IV

Subject	T_3	T_4	D	D^2
1	160	165	5	25
2	176	190	14	196
3	288	325	37	1369
4	270	257	-13	169
5	232	270	38	1444
6	232	310	78	6084
7	250	247	97	9409
8	216	228	12	144
	1824	2092	268	18,840

T = Test number

D = Difference

D^2 = Difference squared

Mean score of test III = 1824

Mean score of test IV = 2092

Difference of mean score = 268

Difference squared = 18,840

THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS DERIVED FROM CORRELATED SCORES FROM SMALL SAMPLES

Test III Compared to Test IV — Left Arm Flexion (Raw Score)

$N = 8$

$\Sigma D = 268$

$\Sigma D^2 = 18,840$

$S_{\bar{D}}$ (estimate of sampling error of $\bar{D}$ $= \dfrac{S_D}{\sqrt{N}} =$

$$\frac{\sqrt{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}}{N-1} \qquad \frac{\sqrt{18,840 - \frac{(268)^2}{8}}}{7}$$

$$\sqrt{N} \qquad \sqrt{8}$$

$S_{\bar{D}} = 13.3$

$\bar{D}$ (Mean Difference $\dfrac{\Sigma D}{N} = \dfrac{268}{8} = 33.5$

$$t = \frac{\bar{D}}{S_{\bar{D}}} = \frac{33.5}{13.3} = 2.512$$

$df = N - 1 = 7$

"t" at .05 level = 2.365

Significant at the .05 level.

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