A COMPARISON OF CABLE TENSIOMETER STRENGTH, 1-R.M. AND 10-RM VALUES OBTAINED IN KNEE EXTENSION

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A COMPARISON OF CABLE TENSIOMETER STRENGTH, 1-RM, AND 10-RM VALUES, OBTAINED IN KNEE EXTENSION

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ABSTRACT

Title.

A Comparison of Cable Tensiometer Strength, 1-RM, and 10-RM Values, Obtained in Knee Extension.

Statement of the Problem.

The problem consists of the following two phases: 1) to determine the relationship between cable tensiometer strength and the 1-RM value; and 2) to determine the percentage of the tensiometer poundage which most nearly corresponds to the 10-RM value.

Methodology.

Two hundred men of the Michigan State University Required Physical Education population were randomly selected, and 187 of this group participated in the experiments. These men were randomly assigned to four levels of all-out performance to determine the value of the 10-RM from tensiometer poundage. The men were contacted in their class and immediately performed the experiments after an explanation of the purpose and procedure involved. The tests administered, in order, were: the tensiometer test; the 1-RM test; and the percentage level all-out repetitions.

Conclusions.

1. The relationship between cable tensiometer strength and the 1-RM capacity as measured in this study is relatively low (r = .6798). The correlation, though significant, is poorer than was anticipated. Apparently being affected either by the unreliability of the 1-RM test or because there may be a poor relationship between static and dynamic strength.

2. The 10-RM value lies between the mean of the 30 per cent level (14.9) and the 40 per cent level (7.9). By interpolation, the 10-RM value was determined to be 37 per cent of the cable tensiometer poundage.

3. The mean of the 1-RM data was found to be 46 per cent of the mean of the cable tensiometer data. These results are contrary to some of the earlier findings.

4. A table for use in the selection of 1-RM and 10-RM treatment levels has been presented.

ACKNOWLEDGEMENTS

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CHAPTER I

INTRODUCTION

During the past decade or two there has been considerable apathy in the field of physical education, rehabilitation, and among medical persons concerning the practice of weight lifting. During World War II, T. L. DeLorme and others[1] initiated the practice of progressive resistance exercises[2] with excellent results. Progressive resistance exercises are weight lifting exercises utilizing the available range of motion of a limb or joint with regular increases in the amount of weight proportional to the strength increase of the particular muscle group in an attempt to regain the normal, or higher, functional strength of that muscle group.

The 1-RM and the 10-RM[3] are the values set by DeLorme and his associates for the administration of the progressive resistance exercise program. It is reasonably

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[1]T. L. DeLorme and A. L. Watkins, Progressive Resistance Exercises: Technic and Medical Application. New York: Appleton-Century-Crofts, Inc., 1951, pp. 1-5.

[2]Originally termed "heavy resistance exercises" but later changed to progressive resistance exercises to be more descriptive of the actual practice.

[3]For definitions of 1-RM and 10-RM see page 2.

difficult and time consuming, however, to determine these values without some guide as to the strength of the muscle group before applying the weight.

Statement of the Problem.

The problem consists of the following two phases: 1) to determine the relationship between cable tensiometer strength and the 1-RM value; and 2) to determine the percentage of the tensiometer poundage which most nearly corresponds to the 10-RM value.

Definition of Terms.

Tensiometer.[4] A gauge for measuring cable tension in which the cable passes over two sectors and, when tension is applied, offsets a third sector (riser) which connects mechanically to the face of the device to permit recording in dial units which are convertable to pounds. (See Figure 2)

Ten Repetition Maximum (10-RM). "The term referring to the greatest weight that can be correctly carried through the available range of motion for 10 repetitions."[5]

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[4]Manufactured by the Pacific Scientific Company, Inc., 1430 Grande Vista Avenue, Los Angeles, California.

[5]T. L. DeLorme, F. E. West, and W. J. Shriber, "Influence of Progressive Resistance Exercises on Knee Function Following Femoral Fractures," Journal of Bone and Joint Surgery. Vol. 32-A, No. 4, 1950, p. 911.

One Repetition Maximum (1-RM). "The term referring to one repetition instead of ten. It represents the maximum volitional effort."[6,7]

Progressive Resistance Exercises. Originally known as "heavy resistance exercises," this is the administration of resistance to movement by use of weights proportional in amount to the strength of the muscle group being exercised. The 1-RM and the 10-RM are values arbitrarily set for the administration of these exercises.

Percentage Level. Refers to the phase of the study in which the subjects for all-out repetitive lifting were assigned selected weight loads. The loads were assigned by taking selected percentages of the quadriceps extension strength measure as determined by the cable tensiometer. The percentage levels utilized were 30, 40, 50, and 60 per cent. The subjects fully extended their assigned amount of weight the maximum number of repetitions possible (all-out). This was done in an attempt to determine which percentage level most nearly corresponds to the ten repetition level.

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[6]Ibid.

[7]There is a question, of course, as to whether the measure is actually the maximum effort possible.

Need For This Study.

The progressive resistance exercise values of 10-RM and 1-RM are empirically derived treatment levels utilized by DeLorme and a host of subsequent workers. Methods of determining these values involve as much as 20 to 30 repetitions through the full range of motion for injured knees at least once each week. This method yields somewhat inaccurate results due to the fatigue resulting from the successive extensions. A simpler and less fatigueing method of arriving at these values would be beneficial both to the patient and the therapist.

With the completion of this study it is hoped that the simply administered tensiometer test might be given and with one maximum contraction the poundage might be determined for the 1-RM and the 10-RM values in the treatment phase.

Limitations of the Study.

1. The test administrator observed in some of the subjects a negative response towards lifting what seemed to be a large amount of weight. It is believed, therefore, that it is possible some of the subjects did not exert as much effort as they were capable of exerting. The subjects, however, in each case seemed to be working all-out.

2. The battery of tests was given with the cable tensiometer test first; the 1-RM value determined immediately afterward; the 10-RM percentage level values immediately following the 1-RM test. The effects upon the accuracy of these values because of the successive pattern of administration is not known and the data are limited by this pattern.

3. In the calculation of the percentage levels from the cable tension strength, the poundage was rounded off to the nearest five pounds, i.e. 76 pounds would be rounded off to 75 pounds and 78 pounds to 80 pounds.

CHAPTER II

REVIEW OF LITERATURE

Progressive resistance exercises are of recent origin, having been started during World War II. The original term of heavy resistance exercise was changed to the term presently used. The original term was inaccurate in describing the technique because of the existing apathy toward weight lifting in general, and the term had the connotation generally associating it with building the largely muscled body.[1]

For the benefits which have been derived from this system of exercises, there seems to have been relatively little research performed to refine the technique. There is ample evidence, however, for the value of this program as the next section indicates.

The main purpose of progressive resistance exercise is for the development of strength, and the technique is based on the physiological "overload principle" utilized by weight lifters.[2] From his observation of weight lifters

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[1]T. L. DeLorme and A. L. Watkins, Progressive Resistance Exercise; Technic and Medical Application. New York: Appleton-Century-Crofts, Inc., 1951, p. 21.

[2]Ibid., pp. 10-11.

exercises DeLorme set the maximum repetitions per exercise bout at ten, thus originating the ten repetition maximum (10-RM). From this he arrived at the one repetition maximum or the 1-RM. This he recommends as an index of strength to be determined "once a week"[3] and recorded.

Value of Progressive Resistance Exercises.

DeLorme[4] lists four outcomes for therapeutic exercise: power, endurance, speed and coordination. He emphasizes that progressive resistance exercises are basically for the development of power and strength as it is necessary to have a certain degree of strength before any of the others can be efficiently developed.

Studies have been made to determine the usefulness of progressive resistance exercises in various orthopedic conditions. Such a study was completed by DeLorme, Schwab, and Watkins[5] on the quadriceps muscles of poliomyelitic patients. Nineteen subjects were used with sixteen of the subjects being tested bilaterally. Three methods of administering the exercises were necessary due to the

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[3]T. L. DeLorme, "Heavy Resistance Exercises," Archives of Physical Medicine. Vol. 27, 1946, p. 612.

[4]Ibid., pp. 607-608.

[5]T. L. DeLorme, R. S. Schwab, and A. L. Watkins, "Response of Quadriceps Femoris to Progressive Resistance Exercises in Poliomyelitic Patients," Journal of Bone and Joint Surgery. Vol. 30, (October, 1948), p. 834.

condition of the muscles. These were: 1) the regular technique in sitting position; 2) the gravity assisting technique with the patient in a prone position; and 3) the hip-knee extension method in the sitting position.

Muscle strength was determined by the use of spring scales and the Lovett muscle grading method. After one to four months, of the 27 muscles involved, 17 were graded higher and ten were rated higher within their grade, i.e. normal, good, fair, poor, trace, zero, etc.

As a result the authors[6] stated:

> "The qualitative and quantitative evidence presented supports the hypothesis that, following acute anterior poliomyelitis, the remaining innervated muscles respond to progressive resistance exercises by an increase in strength and work capacity in much the same manner as normal muscles."

Gallagher and DeLorme[7] studied the effect of progressive resistance exercise on adolescent boys. Twenty-five boys with various injuries of the knee and nine boys with low back strains were studied. Exercise for the knees consisted of knee extension exercises with boot and weight and hip and knee flexion-extension exercises. Exercise for the lower back strains was the trunk extensor exercise

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[6] Ibid., p. 846.

[7] J. R. Callagher and T. L. DeLorme, "The Use of the Technique of Progressive Resistance Exercise in Adolescence," Journal of Bone and Joint Surgery. Vol. 31-A, No. 4, (October, 1949), pp. 847-858.

with weights strapped to the back. The boys with knee injuries ranged from 5 to 60 exercise periods and all increased significantly the strength of their legs. The majority doubled the strength of their legs while some tripled their strength. These boys exercised four days a week with the 1-RM being determined at the beginning of each week.

The exercise periods for the boys with lower back strains ranged from 10 to 48 and all of the boys increased their strength, some doubling and some tripling, or better, the original strength.

Retests of both conditions at varying periods ranging from two to twelve months revealed very little loss of strength in a couple of boys, and the rest maintained or had increased their final test strength.

Ten Repetition Maximum (10-RM).

This treatment level was set by DeLorme.[8] The number of repetitions was empirically derived, based on the practice of weight lifters. The original set of repetitions recommended was 70 to 100, but this number was lowered to 20 to 30 for exercise with heavier loads.[9] This 20 to 30 repetition set is arranged in three bouts of ten repetitions

[8]T. L. DeLorme and A. L. Watkins, Progressive Resistance Exercise: Technic and Medical Application. New York: Appleton-Century-Crofts, Inc., 1951, p. 7.

[9]Ibid., p. 24.

each: the first bout using one-half of the 10-RM load; the second using three-quarters of the 10-RM load; and the third using the full 10-RM load.

The 10-RM load value is determined once each week and the technique for the initial determination is as follows:[10]

> "Starting with the weight of the boot (5 pounds) and increasing by small amounts (1 1/4 to 5 pounds) the patient lifts each weight in ten repetitions. That weight which requires maximum exertion to perform ten repetitions is thus determined."

This value is determined once each week and that amount of weight is used for the week following. The initial weight used in determining the new 10-RM value is the weight exercised for the past week.

A modification of this method was made by Zinovieff[11] and is titled the "Oxford Technique". This modification was made after the author attempted to use DeLorme's original (70-100 repetitions) technique (10-RM) with the result that the patients could not complete the exercise due to fatigue of the quadriceps muscles. This modification of the DeLorme technique emphasizes a reduction instead of an increase in the amount of weight per set of ten repetition bouts and maintains the 100 total repetition

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[10]T. L. DeLorme, "Heavy Resistance Exercises," Archives of Physical Medicine. Vol. 27, 1946, p. 611.

[11]A. N. Zinovieff, "Heavy Resistance Exercises: The 'Oxford Technique'," British Journal of Physical Medicine. Vol. 14, 1951, pp. 129-132.

per set. This change varies, however, in that the patient tries to increase his 10-RM each day by one pound or works on successive days to increase to the one pound extra until it is achieved. Another variation is that during the repetitions, the foot is rested for a second or two between each lift with the weight supported on an adjustable weight support.

Zinovieff tested this modification on 55 out-patient cases with quadriceps weakness. The test resulted in an average girth increase of three-eighths inch every two and one-half weeks. The 10-RM increased on an average of seven pounds every five days, and the absolute strength measured by an iceman's spring scale increased on an average of ten pounds each week.

The advantages claimed by Zinovieff are that the Oxford technique gives less strain on the patients knee and provides a satisfactory increase in size and strength with less difficulty.

One Repetition Maximum (1-RM).

DeLorme[12] also originated the 1-RM test value which is the amount of weight which can be carried through the

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[12]T. L. DeLorme and A. L. Watkins, Progressive Resistance Exercises: Technic and Medical Application. New York: Appleton-Century-Crofts, Inc., 1951, p. 127.

available range of motion, once and once only. DeLorme explains the function and the determination of this value in the following:[13]

> "As previously stated, once a week the patient exerts his maximum quadriceps power (maximum weight that can be lifted with one repetition the knee going into complete extension). This one repetition maximum (1-R.M.) is determined on the same day as the 10 R.M., in the following manner: When the 10-R.M. has been determined, the increases in weight are continued. With each increase beyond the 10-R.M., fewer repetitions can be done, until finally that weight which can be extended only for one repetition with maximum exertion is reached. This is recorded weekly as the index of quadriceps power."

Zinovieff, in using the S.S.L. (single spring lift), gained by use of a spring ice scale, instead of determining the 1-RM, stated: "This figure is more easily and quickly arrived at than is DeLorme's 1-R.M. Furthermore it does not have the disadvantage of fatigueing the quadriceps during assessment, which makes the 1-R.M. an unreliable measure."[14]

Cable Tensiometer Testing.

The cable tensiometer as a device for objectively recording muscle strength was first originated during

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[13]T. L. DeLorme, "Heavy Resistance Exercise," Archives of Physical Medicine. Vol. 27, 1946, p. 612.

[14]A. N. Zinovieff, "Heavy Resistance Exercises: 'Oxford Technique'," British Journal of Physical Medicine. Vol. 14, 1951, p. 130.

World War II by Clarke and Peterson.[15] Eventually, Clarke constructed 38 objective muscle tests involving movements of the finger, thumb, wrist, forearm, elbow, shoulder, neck, trunk, hip, knee, and ankle joints. Research for these tests was conducted in the Physical Education Laboratory at Springfield College, Springfield, Mass.[16]

> "This instrument was originally used to measure the tension of aircraft control cable. Cable tension is determined by measuring the force needed to create offset (on riser) in the cable between two set points (the sectors). This tension may be converted directly into poinds on a calibration chart."

Clarke[17] compared the effectiveness of four muscle strength recording instruments, the cable tensiometer, the Wakim-Porter strain guage, the spring scale, and the Newman myometer.[18]

> "As reflected by objectivity coefficients, the cable tensiometer had the greatest percision for strength testing. It was the most stable and generally useful of the instuments; and was free of most of the faults of the other devices. The strain gauge had a satisfactory degree of precision; but was extremely sensitive to slight tensions, including changes in room temperature. Both the spring scale and the Newman myometer had deficiencies which limited their usefulness.

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[15]H. H. Clarke, Cable-Tension Strength Tests. Chicopee, Mass., 1953.

[16]Ibid., p. 2.

[17]H. H. Clarke, "Comparison of Instruments for Recording Muscle Strength," Research Quarterly. Vol. 25, 1954, pp. 398-411.

[18]Ibid., p. 398.

Wakim and others compared the strain gauge and the tensiometer:[19]

> "Simultaneous readings were taken with the two instruments at angles of pull of 90, 100, 110, and 120 degrees (200 observations on 20 young women). The average power recorded with the strain gauge was 61.1 pounds, whereas with the tensiometer it was 57.0 pounds. The average difference in readings between the two instruments was 4.1 pounds, with the strain gauge giving higher results in 183 observations, the tensiometer giving higher readings in 10, and the two giving identical recordings in 7. Since the two instruments gave identical readings under static conditions, it seemed as if the lower results with the tensiometer were due to friction within the instrument."

Clarke and others[20] revised their original form of administering the cable tensiometer test for quadriceps strength with a higher objectivity derived from the new method. In this method the position is the same as in the original test except that the hands are placed on the sides of the table and to the rear with the subject leaning backward instead of the subject crossing his arms on his chest as in the original test. The reason for this change is stated by Clarke:[21]

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[19]K. G. Wakim, J. W. Gersten, E. C. Elkins, and G. M. Martin, "Objective Recording of Muscle Strength," Archives of Physical Medicine. Vol. 31, (February, 1950), p. 95.

[20]H. H. Clarke, E. C. Elkins, G. M. Martin, and K. G. Wakim, "Relationship Between Body Position and the Application of Muscle Power to Movements of the Joints," Archives of Physical Medicine. Vol. 31, (February, 1950).

> "In the original testing position, the quadriceps muscles are in a shortened position, and the hamstring muscles offer countertension. In the revised position, the quadriceps muscles are more nearly at their full length and the tension of the hamstring muscles is not so great."

Related Studies.

Klein and Johnson[22] conducted an experiment with six patients with the original purpose of gaining information on the effect of unilateral exercise which later developed into a method of determining the value of the 10-RM in relation to the tensiometer test. These six subjects were exercised according to the "Oxford technique" of maximum lift first bout of ten repetitions and then reducing the weight during successive bouts. The subjects consisted of three post-menesectomies and three muscle atrophy cases resulting from athletic injuries.

The 1-RM values were determined with two of the patients, and ten pounds were dropped of for the 10-RM exercise. The patients were capable of doing over the 10-RM limit with this weight. The second day five pounds were dropped off of the 1-RM value, and during the three weeks following the "ten R.M. capacity was established by reducing the maximum single by five pounds." All of the other patients were

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[22]K. K. Klein and E. Johnson, "Research: A Method of Determining the Maximum Load, for Ten Repetitions, in Progressive Resistance Exercises for Quadriceps Development," The Journal of the Association for Physical and Mental Rehabilitation. Vol. 7, No. 4 (July-August, 1953), pp. 130-131.

tested on this method and it was found to work for them. The tensiometer readings were established as equaling about three times the 1-RM values.

Hettinger and Muller[23] report a new method of developing muscle strength. They give evidence that exerting two-thirds of maximum force for a period of six seconds per day will increase the strength of a muscle 5 per cent per week until it reaches its maximum hereditary strength.

McCloy[24] indicates, however, that the benefits of exercise should be considered into the administration of this new method of strength development. Strength is not the only value gained by exercise although it is important to exercise. He suggests that this technique be tried along with exercise through full range of motion to get better results.

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[23]Th. Hettinger and A. E. Muller, "Muskelleistung und Muskeltraining," Arbeitsphysiologie. Vol. 15, No. 2 (October, 1953), pp. 116-126.

[24]C. H. McCloy, "Something New Has Been Added," The Journal of the Association for Physical and Mental Rehabilitation. Vol. 9, No. 1 (January-February, 1955), pp. 3-4.

CHAPTER III

METHODOLOGY

Introduction.

This study was undertaken in an attempt to establish the cable tensiometer test as a simply administered means of determining the 1-RM and the 10-RM treatment levels. Two hundred subjects were selected randomly from the Michigan State University required male physical education population. All of the participating subjects were measured for knee extension strength of their strongest leg using the cable tensiometer and then subsequently tested on the 1-RM and the percentage level all-out repetition tests. The data obtained on these subjects were then correlated and tabled. The procedures involved are described in detail in this chapter.

Selection of Subjects.

Two hundred men were selected as a representative sample of the Michigan State University Physical Education Instructional Program (required) population. These men were chosen randomly from 2,342 by use of numbered class lists and a table of random numbers.[1] Eighty two of the

[1] M. G. Kendall and B. B. Smith, Tables of Random Sampling Numbers, London: Cambridge University Press, 1939.

one hundred and eighty-seven men of the two hundred randomly chosen participated in the experiments. Thirteen men did not wish to participate, and no attempt was made to substitute for these thirteen men.

The total sample was numbered consecutively from 1 to 200. This number was used to place them into one of the four percentage level catagories by the following method: Each number was divided by four and the remainder of the division used for category placement. Remainders of 0, 1, 2, or 3 were placed in the 30%, 40%, 50%, or 60% level groups respectively.

Tests Utilized.

The cable tensiometer test was administered as described by Clarke[2] with a change made in the table to facilitate the reading of the tensiometer[3] (see Figures 1 and 2). This change was accomplished by placing a moveable pulley at the rear of the table and fixing the cable just above seat level at the back of the table. The pulley was

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[2]H. H. Clarke, Cable-Tension Strength Tests. Chicopee, Mass.: Brown-Murphy Co., 1953, p. 29.

[3]Bryant W. Pocock, research engineer at Michigan State University was consulted regarding the change. He stated that the cable tension would be the same at the measurement point in this table as in a direct hook-up like Clarke's, neglecting the slight friction of a single pulley.

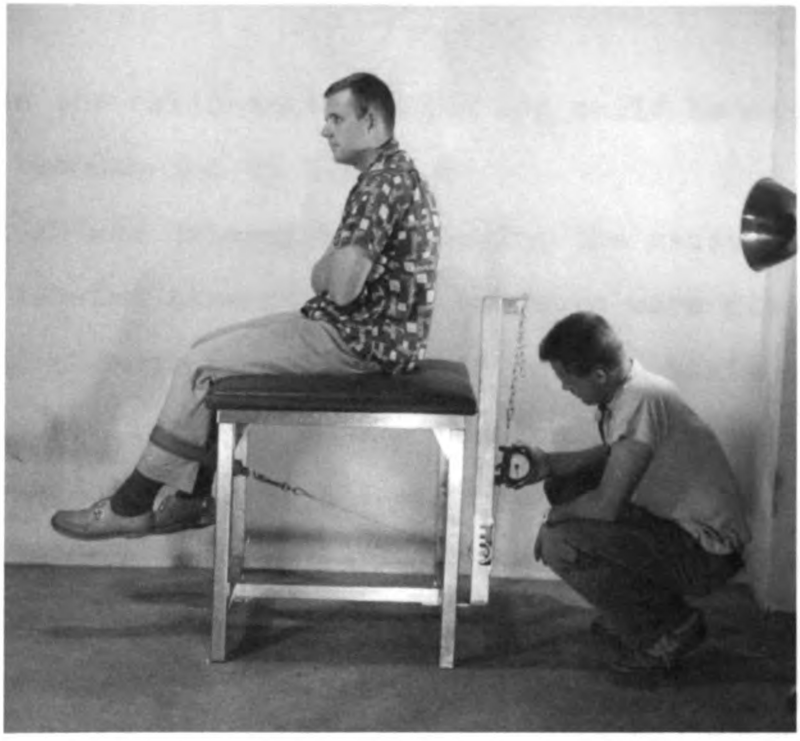

Figure 1. Table and equipment as used in tensiometer test.

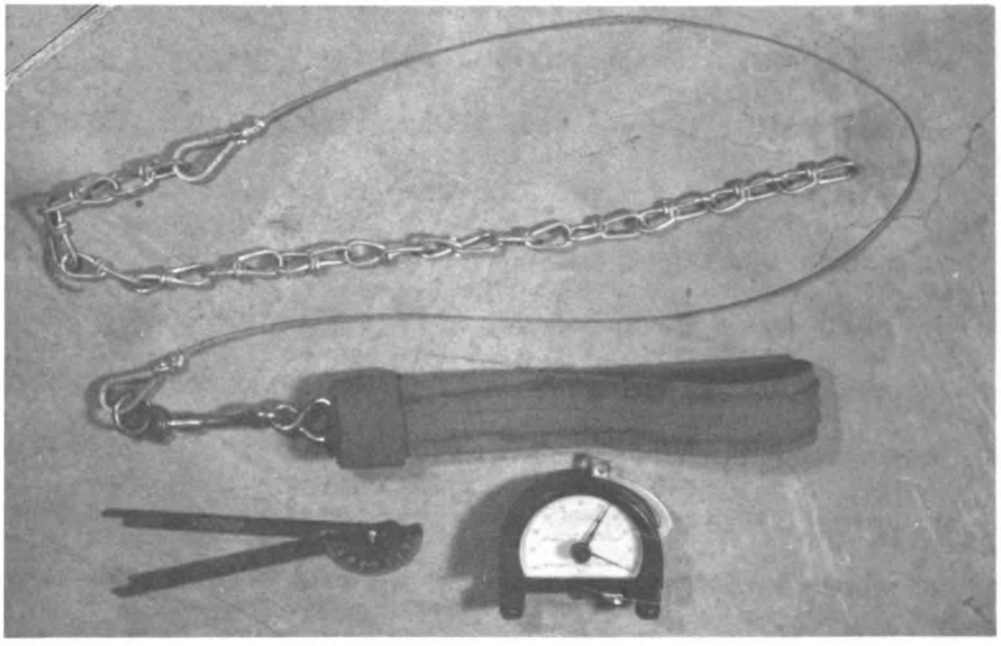

Figure 2. Equipment utilized in administering the tensiometer test. Top: Chain, cable, and strap apparatus. Right: Tensiometer. Left: Goniometer for setting joint angles.

moveable so the cable angle at the leg could be maintained at 90° as recommended by Clarke.[4]

The 1-RM was determined following the measurement of the cable tension strength. The subjects were given various weights, and through several repetitions the maximum weight which could be lifted to full extension once was determined.

The percentage level all-out repetition test followed and concluded the tests. In this test the subjects exercised with the assigned percentage levels of the tensiometer poundage. Repetitions were continued until fatique made full extension impossible.

Techniques in Collection.

Subject Contact. When the men were selected, the information, including name, class sport, class section, instructor's name, and hours and days the class was scheduled to meet, was recorded on a separate card for each man. (see Appendix A). These cards were then arranged according to class and section and the men were contacted in their class just prior to performing the experiment. The instructors had been notified approximately one week in advance and arrangements made to excuse the men for the testing period. The purpose of the experiment and the procedures were explained to the subjects who then

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[4]H. H. Clarke, Op. Cit., p. 7.

participated in the experiment one at a time. The subjects were very cooperative and demonstrated interest in the experiment. Thirteen of the men were unable to participate for various reasons. No attempt was made to replace them.

Administering the Tests. The tests were given as they are arranged on the card (see Appendix A). The men were tested one at a time for the complete test.

Height and weight measurements are not accurate in all cases as the subjects were dressed in various clothing at the time of their contact and the men usually had classes to meet during the next scheduled class hour. Requiring clothing change would have hindered them in meeting with their classes on time. Therefore, height and weight are merely indications of the true measurements.

Tensiometer test: The men were requested to sit on the table facing the proper direction with their hands placed at the back of the table[5] and the back of the knee

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[5]H. H. Clarke, E. C. Elkins, G. M. Martin, and K. G. Wakim, "Relationship Between Body Position and the Application of Muscle Power to Movements of the Joints," Archives of Physical Medicine. Vol. 31 (February, 1950), pp. 81-89. (This is a revision of the original method of performing this test. In the original test the subject crossed his arms over his chest. When the subject was allowed to do this, his upper body position changed, possibly affecting the reading as he either leaned forward or backward when pulling against the cable. The following is an explanation for the revision of this new test position: "The position is the same as for the original test except that the subject is sitting and leaning backward with the arms extended to the rear and the hands grasping the sides of the table . . . In the original testing position the quadriceps muscles are in a shortened position, and the hamstring muscles offer counter tension. In the revised position, the quadriceps muscles are more nearly at their full length and the tension of the hamstring muscles is not so great." p. 85.

against the front edge of the table. Clarke's method of testing knee extension was then conducted with the revision of the hands at the back of the table rather than on the side to prevent flexion of the arms.[6,7]

Two readings were taken successively and recorded. The mean score of the two readings was used except in variations of more than four places on the dial on the face of the tensiometer. If the readings were more than four places apart, the highest recorded number was used as the indication for poundage pulled.

1-RM test: This test was administered directly after the tensiometer test with no rest except for the change from the tensiometer strap to the boot and weights for determination of the 1-RM.

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[6]The writer found that with the hands at the side of the table, some subjects were inclined to bend their elbows upon extension of the leg. Therefore, the subjects were required to place their hands on the back edge of the table and to keep their elbows straight. The small table top made this applicable. With the hands at the back of the table it was more difficult to bend the elbows, and a more consistent position and recording is obtained since the subjects concentrate on the leg extension instead of gaining advantage by leaning backward. Body position was changed slightly, if at all, because the size of the table top was small and the back edge of the table was close to the subjects sitting position.

[7]H. H. Clarke, Cable-Tension Strength Tests. Chicopee, Mass.: Brown-Murphy Co., 1953, p. 29.

The 1-RM poundage was determined by the addition or subtraction of weight with each extension of the leg until the amount of weight was too much to be lifted to full extension once. The subjects were not told how much they were lifting until the experiment was completed. The subjects hands were placed at the back of the table as in the tensiometer test. The same table was used in all three tests.

A riser was placed under the knee at the front edge of the table as recommended by DeLorme and Watkins.[8] When the subject was in the correct position for knee extension with weights applied to the boot, he was instructed to lift the boot as high as possible without swinging the weight or kicking it up and to keep his arms straight while doing this.

The weight of the boot was not figured into the poundage lifted as the same boot, bar, and clamps were used throughout the testing. The smallest weight used was five pounds. Smaller denominations of two and one-half pounds would be necessary in using the 1-RM in treatment but is not necessarily needed in determining raw weights on normal knees. The 1-RM determined in this manner is not precisely

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[8] T. L. DeLorme and A. L. Watkins, Progressive Resistance Exercises: Technic and Medical Application. New York: Appleton-Century-Crofts, Inc., 1951, p. 92.

accurate anyway, since the number of extensions required varies with each person and the degree of fatigue would be different according to the number of extensions performed.

The men were not given any more rest than was obtainable during the changing of the weight. While the weights were being changed, the subject was in a half-sit and half-stand position at the front of the table. The weight of the boot was lifted and held by the administrator of the tests until the subjects were ready for extension so as not to tire the muscles more than necessary.

10-RM test: This test was broken down into the four percentage levels and followed the administration of the 1-RM test. The poundage for the percentage level was arrived at with the use of the table in Appendix B. The subjects were instructed to lift the weight on the boot at a slow rate of repetition allowing a pause before each extension to avoid advantage gained by swinging the weight and also to get full extension each time. The same leg was used throughout the three tests. The position of the subject for the 10-RM test was the same as for the 1-RM test. The number of pounds lifted and the number of repetitions performed were recorded in their proper places on the individuals card immediately after each test.

Before administering any of the three tests, the subjects were questioned as to whether they had ever injured either leg and were assured that there was no danger in the performance of these tests. The stronger leg according to the opinion of the subject, or the better leg which was not injured was used for the three tests.

Methods of Statistical Analysis.

The coefficient of Correlation was determined for the tensiometer and the 1-RM data. The mean, standard deviation and standard error of the mean of the two tests were also computed for these data.

The means, standard deviations, and standard error of the means was calculated for the four percentage levels of the 10-RM in an attempt to determine which percentage or two percentages most nearly corresponded to the actual 10-RM value.

The cable tensiometer and 1-RM data and the corresponding 10-RM percentage level data (interpolated) were then tabled in McCall[9] T-Score Tables utilizing the 6 sigma range.

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[9]J. F. Bovard, F. W. Cozens, E. P. Hagman, Tests and Measurements in Physical Education. (Third edition; Philadelphia and London: W. B. Saunders Company, 1950), p. 317.

CHAPTER IV

ANALYSIS AND PRESENTATION OF DATA

In an attempt to determine the relationship between cable tension strength tests and the one repetition maximum (1-RM) and the ten repetition maximum (10-RM) values this study was performed. One hundred and eighty-seven men of the two hundred man sample performed in the experiment. The subjects, ranging in age from 17 to 27 were randomly selected from the Michigan State University male required physical education classes (total enrollment, 2,342).

The subjects were tested successively for cable tension strength, 1-RM poundage value, and in the all-out lifting of a weight percentage of the poundage recorded on the cable tensiometer test. The last test was an attempt to determine which percentage of the cable tensiometer test poundage most nearly approximated the 10-RM value. The subjects were assigned to the arbitrarily selected 30, 40, 50, and 60 per cent levels. The method of assignment was to divide by four the consecutive number of the subject's selection. The remainder of the division determined the assignment, i.e. remainders of 0, 1, 2, 3

were assigned to the 30, 40, 50, or 60 per cent levels respectively.

Analysis of Data.

The data were analysed in the following manner: The cable tensiometer strength poundage was correlated with the 1-RM value and the standard deviation and the standard error of the mean determined on each. McCall's T-Score formula, using the 6 sigma range, was then utilized and standard score tables developed for the two values.

The percentage all-out repetition scores were then averaged and the standard deviation and standard error of the mean were determined. The approximate weight value of the 10-RM was then determined by interpolation from the above mentioned results. Using this interpolation value the 10-RM value was added to the above mentioned standard score tables as a rough estimate of the 10-RM value from the cable tensiometer results. It is to be noted, however, that the 10-RM values are not actually standard score data but were arrived at through multiplication of the cable tensiometer score by the percentage. This methodology, of course, has strict limitations, but the author considers the method presented more objective than any method presented heretofore.

Results.

Cable tensiometer poundage and 1-RM poundage: A coefficient of correlation of .6798 was found between the cable tensiometer poundage and the 1-RM poundage. This correlation is highly significant though not as high as had been expected. The $\frac{r}{\sigma_r}$ was 9.30 which is considerably greater than the 2.58 value necessary to conclude with confidence the universe value for r is greater than zero.[1]

The mean value of the cable tensiometer poundage was determined at 206.27 pounds. The standard deviation equaled 50.97 pounds and the range was from 105 to 340 pounds. The standard error of the mean was 3.73 pounds.

The mean value of the 1-RM poundage was 96.71 pounds. The standard deviation was 21.06 and the range from 50 to 170 pounds. The standard error of the mean was 1.540 pounds. Table I lists these figures.

TABLE I

A COMPARISON OF THE CABLE TENSIOMETER AND 1-RM RESULTS

	M(lbs.)	σ	σ_M	Range High	Range Low	N
Tensiometer -	206.27	50.97	3.73	340	105	187
1-RM -	96.71	21.06	1.54	170	50	187

[1]Quinn McNemar, Psychological Statistics, New York: John Wiley and Sons, Inc., 1949, p. 122.

Cable Tensiometer Percentage Level All-Out Repetitions. The mean number of all-out repetitions the subjects were capable of at the various percentage levels are as follows: 30% = 14.9; 40% = 7.9; 50% = 3.4; and 60% = .29. The value of the 10-RM lies between the 30 per cent and 40 per cent levels of the tensiometer values. The percentage equivalent to the 10-RM, by interpolation, is approximately 37 per cent of the tensiometer poundage.

Table II lists the ranges of the various percentage levels according to pounds lifted and number of repetitions.

TABLE II

PERCENTAGE LEVEL ALL-OUT REPETITIONS; RANGES OF WEIGHTS LIFTED AND REPETITIONS PERFORMED IN THE VARIOUS PERCENTAGE LEVELS

	30%		40%		50%		60%	
	Lbs.	Reps.	Lbs.	Reps.	Lbs.	Reps.	Lbs.	Reps.
Low Values -	35	9	44	0	65	0	65	0
High Values -	110	26	130	23	170	17	200	7

Table III lists the mean values of the pounds lifted and the number of repetitions with the standard error of the mean for each. It is to be noted the 10-RM value lies between the 30 and 40 per cent levels. By interpolation the value is approximately equal to 37 per cent.

TABLE III

ALL-OUT PERCENTAGE LEVEL VALUES

Percentage Levels	M (Lbs.)	σ_M	M-Repetitions	σ_M	N
30	60.9 ±	2.7	14.9 ±	2.02	47
40	86.6 ±	3.4	7.9 ±	.98	43
50	101.6 ±	4.0	3.4 ±	.76	49
60	125.7 ±	4.7	.29 ±	1.88	48

Standard Score Tables. Table IV was arrived at by use of McCall's T-Score formula for equal intervals.[2] This table is an indication of the weights which may be used for treatment. The table would be used in the following manner: A subject would be administered the cable tensiometer test and the poundage would be determined from the tensiometer calibration chart. When this value is found the administrator would use the 1-RM and the 10-RM values which will be directly across in the next two columns respectively.

The mean of the 1-RM data was 96.7 pounds, which is 46 per cent of the mean of the tensiometer data. These

[2]J. F. Bovard, F. W. Cozens, and E. P. Hagman. Tests and Measurements in Physical Education. Third edition, Philadelphia and London: W. B. Saunders Company, 1950, p. 317.

TABLE IV

TENSIOMETER AND 1-RM STANDARD SCORE TABLES

Standard Score	Percentile Score	Tensiometer Pounds	1-RM Pounds	10-RM* Pounds
100	99.9	359	160	133
95	99.7	344	153	127
90	99.2	329	147	122
85	98.2	313	141	116
80	96.4	298	135	110
75	93.3	283	128	105
70	88.4	268	122	99
65	81.6	252	116	93
60	72.6	237	109	88
55	61.8	222	103	82
50	50.0	206	97	76
45	38.2	191	90	71
40	27.4	176	84	65
35	18.4	160	78	59
30	11.5	145	72	54
25	6.7	130	65	47
20	3.6	115	59	42
15	1.8	99	53	37
10	.8	84	46	31
5	.4	69	40	25
0	.1	53	34	20

*The 10-RM values are not based on the total distribution. These values were arrived at by multiplying 37% times the tensiometer value for a rough estimate of that standard score level.

results are contradictory to those of Klein[3] who stated the 1-RM measures were approximately one-third of the tensiometer values.

Discussion.

The method presented is rough and is yet to be tested. The advantage lies in its simplicity and objectiveness. There are, however, serious limitations to the technique before it can be generally adopted: 1) The lowness of the correlation between the tensiometer and 1-RM results indicate that either the 1-RM value is too unreliable or that there is a difference between the static tensiometer test used and the dynamic 1-RM test. Ouellette[4] in studying the effects of quadriceps weight training on leg speed obtained significant increases in the 1-RM but not in tensiometer results following a seven-week training program; 2) The table, as presented, assumes the Interpolation between the 30 per cent and the 40 per cent levels to be correct. There is no assurance the data are linear as the interpolation would assume. The data, in fact,

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[3]K. K. Klein and E. Johnson, "Research: A Method of Determining the Maximum Load, For Ten Repetitions, In Progressive Resistance Exercises For Quadriceps Development," The Journal of the Association For Physical and Mental Rehabilitation, Vol. 7, No. 4, July-August, 1953, pp. 130-131.

[4]R. C. Ouellette, "The Effect of Quadriceps Development on Sprint Running Time." Unpublished Master's thesis, Michigan State University, East Lansing, August, 1955.

appear to be curvilinear when percentage values are plotted with repetitions. The table also assumes the 37 per cent value is applicable at both the top and bottom of the scale. There is no assurance this is true though the standard error of the mean at the 40 per cent level is less than one repetition. The table, however, is easily used and is objective. The value of the method will have to be determined by further investigation.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary.

One hundred and eighty-seven of a randomly selected two hundred men from the Michigan State University male required physical education classes participated in a battery of three tests. The tests included: Cable tensiometer strength, one repetition maximum, and a tensiometer poundage percentage level all-out repetition test. The purpose of the experiment was 1) to determine the relationship between the cable tensiometer test and the 1-RM test and 2) to determine what percentage of the cable tensiometer poundage most nearly equaled the ten repetition value. A table for the selection of the 1-RM and 10-RM treatment levels from the simply administered cable tensiometer test was arrived at for an easier and more objective determination of the two measures.

Conclusions.

1. The relationship between cable tensiometer strength and the 1-RM capacity as measured in this study is relatively low (r = .6798). The correlation, though significant, is poorer than was anticipated. Apparently being affected either by the unreliability of the 1-RM

test or because there may be a poor relationship between static and dynamic strength.

2. The 10-RM value lies between the mean of the 30% level (14.9) and the 40% level (7.9). By interpolation, the 10-RM value was determined to be 37% of the cable tensiometer poundage.

3. The mean of the 1-RM data was found to be 46% of the mean of the cable tensiometer data. These results are contrary to some of the earlier findings.

4. A table for use in the selection of 1-RM and 10-RM treatment levels has been presented.

Recommendations.

1. The table for use in the selection of 1-RM and 10-RM treatment levels merits further investigation in longitudinal studies.

2. A further study should be made of the 37% value to determine its accuracy at selected standard score levels from 0 to 100.

3. A longitudinal study utilizing different numbers of repetitions should be completed to determine the validity of the 10-RM measure.

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BIBLIOGRAPHY

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APPENDIX

APPENDIX A

Card For Recording Data.

Number _____ _____

Name_____

Address_____

Class Sport_____

Section_____

Instructor_____

Class Hours: M-W-F T-Th

_____/_____

Age_____

Weight _____lbs.

Height _____ft. _____in.

Mid-leg Length _____in.

Tension Strength

Raw _____/_____ Lbs._____

1-RM _____lbs.

10-RM: percentage_____ lbs._____

Repetitions_____

Comments:

APPENDIX B

Table for Determination of Percentage Level All-Out Repetition Poundage From Cable Tensiometer Reading.

Tensiometer Raw	Lbs.	percentage levels 30%	40%	50%	60%
19	50	15	20	25	30
	55	16.5	22	27.5	33
22	60	18	24	30	36
	65	19.5	26	32.5	39
25	70	21	28	35	42
	75	22.5	30	37.5	45
28	80	24	32	40	48
	85	25.5	34	42.5	51
31	90	27	36	45	54
	95	28.5	38	47.5	57
34	100	30	40	50	60
	105	31.5	42	52.5	63
38	110	33	44	55	66
	115	34.5	46	57.5	69
41	120	36	48	60	72
	125	37.5	50	62.5	75
43	130	39	52	65	78
	135	40.5	54	67.5	81
46	140	42	56	70	84
	145	43.5	58	72.5	87
48	150	45	60	75	90
	155	46.5	62	77.5	93
50	160	48	64	80	96
	165	49.5	66	82.5	99
52	170	51	68	85	102
	175	52.5	70	87.5	105
54	180	54	72	90	108
	185	55.5	74	92.5	111
56	190	57	76	95	114
	195	58.5	78	97.5	117
58	200	60	80	100	120
	205	61.5	82	102.5	123
60	210	63	84	105	126
	215	64.5	86	107.5	129
61	220	66	88	110	132
	225	67.5	90	112.5	135
63	230	69	92	115	138
	235	70.5	94	117.5	141
64	240	72	96	120	144
	245	73.5	98	122.5	147
66	250	75	100	125	150
	255	76.5	102	127.5	153
67	260	78	104	130	156
	265	79.5	106	132.5	159
69	270	90	108	135	162
	275	91.5	110	137.5	165
70	280	93	112	140	168
	285	94.5	114	142.5	171
72	290	96	116	145	174
	295	97.5	118	147.5	177
73	300	99	120	150	180
	305	100.5	122	152.5	183
74	310	102	124	155	186
	315	103.5	126	157.5	189
75	320	105	128	160	192
	325	106.5	130	162.5	195
76	330	108	132	165	198
	335	109.5	134	167.5	201
78	340	111	136	170	204
	345	112.5	138	172.5	207
79	350	114	140	175	210
	355	115.5	142	177.5	213
80	360	117	144	180	216
	365	118.5	146	182.5	219
81	370	120	148	185	222
	375	121.5	150	187.5	225
82	380	123	152	190	228
	385	124.5	154	192.5	231
84	390	126	156	195	234
	395	127.5	158	197.5	237
85	400	129	160	200	240

APPENDIX B

Table for Determination of Percentage Level All-Out Repetition Poundage From Cable Tensiometer Reading.

Tensiometer Raw	Lbs.	percentage levels 30%	40%	50%	60%
19	50	15	20	25	30
	55	16.5	22	27.5	33
22	60	18	24	30	36
	65	19.5	26	32.5	39
25	70	21	28	35	42
	75	22.5	30	37.5	45
28	80	24	32	40	48
	85	25.5	34	42.5	51
31	90	27	36	45	54
	95	28.5	38	47.5	57
34	100	30	40	50	60
	105	31.5	42	52.5	63
38	110	33	44	55	66
	115	34.5	46	57.5	69
41	120	36	48	60	72
	125	37.5	50	62.5	75
43	130	39	52	65	78
	135	40.5	54	67.5	81
46	140	42	56	70	84
	145	43.5	58	72.5	87
48	150	45	60	75	90
	155	46.5	62	77.5	93
50	160	48	64	80	96
	165	49.5	66	82.5	99
52	170	51	68	85	102
	175	52.5	70	87.5	105
54	180	54	72	90	108
	185	55.5	74	92.5	111
56	190	57	76	95	114
	195	58.5	78	97.5	117
58	200	60	80	100	120
	205	61.5	82	102.5	123
60	210	63	84	105	126
	215	64.5	86	107.5	129
61	220	66	88	110	132
	225	67.5	90	112.5	135
63	230	69	92	115	138
	235	70.5	94	117.5	141
64	240	72	96	120	144
	245	73.5	98	122.5	147
66	250	75	100	125	150
	255	76.5	102	127.5	153
67	260	78	104	130	156
	265	79.5	106	132.5	159
69	270	90	108	135	162
	275	91.5	110	137.5	165
70	280	93	112	140	168
	285	94.5	114	142.5	171
72	290	96	116	145	174
	295	97.5	118	147.5	177
73	300	99	120	150	180
	305	100.5	122	152.5	183
74	310	102	124	155	186
	315	103.5	126	157.5	189
75	320	105	128	160	192
	325	106.5	130	162.5	195
76	330	108	132	165	198
	335	109.5	134	167.5	201
78	340	111	136	170	204
	345	112.5	138	172.5	207
79	350	114	140	175	210
	355	115.5	142	177.5	213
80	360	117	144	180	216
	365	118.5	146	182.5	219
81	370	120	148	185	222
	375	121.5	150	187.5	225
82	380	123	152	190	228
	385	124.5	154	192.5	231
84	390	126	156	195	234
	395	127.5	158	197.5	237
85	400	129	160	200	240

MICHIGAN STATE COLLEGE
DEPARTMENT OF PHYSICAL EDUCATION, HEALTH AND RECREATION FOR MEN

GRADUATE STUDIES AND RESEARCH

APPENDIX C.
TABULATION SHEET

TOPIC Tables of Measures of 187 Randomly Selected Michigan State University (required) Male Physical Education Students (Knee Extension).

DATE OF TABULATION June-July, 1955

TABULATED BY Donald Bertram Richards

-187-

	NAME	AGE	WEIGHT	HEIGHT	MID-LEG LENGTH	TENSION RAW	PULL LBS.	1-RM	10-R.M. %AGE	10-R.M. LBS.	REPS.
1	chernjowski	23	162	6'½"	7½"	58-54	190	80	30	55	17
2	griswold	19	145	5'10½	8	64-62	230	85	30	70	16
3	smith	18	150	6'	8½	56-52	180	100	30	55	21
4	lundin	18	185	5'9½	8	80-76	340	145	30	110	10
5	willis	19	158	5'11	8	66-68	260	120	30	80	12
6	plugge	18	176	5'10½	8	60-64	225	100	30	70	18
7	sperry	19	167	5'11	8½	70-66	265	120	30	80	14
8	etheridge	24	178	6'½	8	65-65	245	125	30	75	11
9	feldpausch	18	137	5'5	7½	67-67	260	100	30	80	8
10	Sutton	18	156	6'	8½	57-57	195	100	30	60	13
11	tacey	20	162	6'	8	65-65	245	75	30	75	7
12	vandyke	22	180	6'2	8	76-76	330	135	30	110	10
13	black	20	177	6'½	8½	48-48	150	70	30	45	26
14	winquist	20	169	6'1½	8	48-50	155	90	30	45	23
15	field	20	150	5'9	8	46-46	140	90	30	45	23
16	morris	20	145	5'10½	8	50-50	160	80	30	50	16
17	silverthorne	24	207	5'10	7½	52-50	165	80	30	50	13
18	millar	18	161	6'2½	8½	56-58	195	90	30	60	14
19	granger	19	180	6'2	8	38-38	110	70	30	35	13
20	sisk	25	180	6'	8	44-44	135	75	30	40	20
21	jeter	19	220	6'1½	9	46-46	140	100	30	40	20
22	campbell	18	167	5'10½	7½	56-56	190	80	30	55	15
23	molitor	19	177	6'2	8	42-42	125	90	30	40	20
24	bagley	18	172	5'10½	7½	54-58	190	75	30	55	15
25	goller	18	178	6'	7½	38-38	110	70	30	35	20
26	carr	19	154	5'8½	8	48-46	145	60	30	45	15
27	kennedy	22	156	5'10	8	50-52	165	60	30	50	13
28	rigoni	19	165	5'10½	8	64-64	240	120	30	70	13
29	kershner	18	154	5'10½	7½	46-46	140	90	30	40	17
30	neumann	18	169	5'9	7½	44-44	135	80	30	40	18
31	brenner	19	147	6'1½	8½	70-68	270	80	30	90	4
32	juliano	18	131	5'5½	7½	67-67	260	105	30	80	15
33	eldredge	20	138	6'1	8	56-56	190	70	30	55	17
34	schramek	18	166	5'8½	7	52-52	170	75	30	50	15
35	may	20	157	5'11	8	55-57	190	85	30	55	15
1	hierholzer	19	211	6'½	8	64-64	240	105	30	70	20
2	barker	19	202	5'11½	8	56-54	185	105	30	55	22
3	brendal	19	135	5'7½	7½	46-48	145	75	30	45	18
4	hedden	19	183	6'5	9	74-72	300	135	30	100	11
5	moorhouse	19	143	5'7	7½	50-48	155	85	30	45	20
6	Wilson	26	176	6'½	8	54-52	175	90	30	55	13
7	Pishos	20	143	5'4¾	6¾	62-62	225	80	30	70	10
8	rouse	20	167	5'10½	8	70-70	280	105	30	95	8
9	price	18	158	5'11½	8	50-56	175	85	30	55	18
10	sabo	19	168	5'8½	7½	69-67	265	95	30	80	14
11	strobel	20	140	5'9½	7½	44-44	135	85	30	40	22
12	rigotti	18	146	5'10½	8	60-61	220	90	30	65	4
13	gest	18	222	6'5	9	76-74	320	110	40	130	--
14	juncker	18	147	5'9½	7½	64-70	260	115	40	105	7
15	belfore	19	156	5'11	8	42-44	130	80	40	50	14
16	hane	18	168	6'1½	8	69-67	265	110	40	105	7
17	grabman	18	172	5'11½	8	64-64	240	105	40	95	6
18	roberts	19	130	5'6	7½	54-56	185	75	40	75	--
19	thompson	19	175	6'	7½	48-50	155	80	40	60	8
20	shuert	20	170	6'6	9	72-68	280	95	40	110	--
21	oliver	19	161	5'10	8	66-66	250	100	40	100	--
22	mahr	19	164	6'	8	70-70	280	110	40	110	--
23	jacobs	18	195	6'3	8	68-68	265	95	40	105	--
24	semmens	18	228	5'11½	8	75-77	330	145	40-	130	12
25	ratz	19	146	5'10½	7½	60-62	220	95	40	90	14
26	radzville	19	182	6'	8	68-68	265	130	40	105	2
27	mcConnell	18	142	5'8½	7	58-62	210	95	40	85	6
28	old	19	172	6'1½	8	47-47	145	65	40	60	8
29	dahlin	18	162	6'1	8	39-41	117	75	40	45	12
30	jenkins	19	139	6'	7	62-62	225	100	40	90	10
31	kilzer	18	182	5'11	7½	50-52	165	110	40	65	16
32	dilley	19	174	5'11¾	8½	55-55	165	95	40	65	16
33	baker	19	183	5'10½	7½	62-66	240	130	40	95	14
34	fitzpatrick	20	171	5'10½	7½	54-54	180	95	40	70	23
35	jensen	18	134	6'½	7½	46-46	140	80	40	55	10

	NAME	AGE	WEIGHT	HEIGHT	MID-LEG LENGTH	TENSION RAW	PULL LBS.	1-RM	10-R.M. %AGE	10-R.M. LBS.	REPS.
1	LOBAUGH	19	147	5'10	8	42-42	125	80	40	50	17
2	hollis	19	148	5'10	7½	64-64	240	110	40	95	11
3	beron	19	151	5'7½	7½	38-38	110	70	40	45	15
4	young	19	153	5'9½	7½	42-46	135	50	40	55	12
5	kraft	19	153	5'9	7½	72-72	290	140	40	115	5
6	ellsworth	21	166	6'1½	8	66-66	250	105	40	100	--
7	covell	20	160	5'9½	7½	66-68	260	105	40	105	--
8	burke	18	158	6'1	8	58-58	200	100	40	80	6
9	frazer	18	153	5'7½	7½	52-50	165	95	40	65	16
10	ertel	23	143	5'10½	7½	66-64	245	120	40	100	10
11	lipa	19	182	6'1	7½	62-60	220	115	40	90	15
12	pabst	19	140	6'1	8	52-52	170	60	40	70	--
13	king	19	164	6'½	7½	70-68	270	110	40	110	--
14	langley	20	182	5'8½	8	64-66	245	110	40	100	4
15	lamphere	18	169	6'	8	58-62	210	95	40	85	10
16	gippert	19	193	6'4½	8½	71-72	290	125	40	115	7
17	hunter	18	139	5'8½	7½	56-54	185	75	40	75	--
18	gallagher	18	168	6'	8	66-64	245	90	40	100	--
19	danenberg	26	122	5'3½	7	58-60	205	100	40	80	6
20	lynch	19	151	5'10½	7½	56-56	190	90	40	75	18
21	mcDaniel	19	150	5'10¼	7½	50-54	170	95	50	85	6
22	johnson	21	155	5'11	7½	68-70	270	110	50	135	--
23	adamski	27	166	5'11	8	62-66	240	80	50	120	--
24	rodgers	19	165	5'10½	8	74-80	335	130	50	170	--
25	ebersol	19	170	6'½	8	52-52	170	85	50	85	--
26	mcIntyre	18	148	5'10	7½	66-64	245	110	50	125	--
27	hohisel	19	210	6'2½	8½	50-50	160	110	50	80	11
28	fox	18	162	5'9½	7½	66-66	250	100	50	125	--
29	brennan	19	168	5'10	8	68-68	265	120	50	135	--
30	smith	20	128	5'7	7½	52-54	175	80	50	90	--
31	ufland	18	141	6'	8	58-54	190	80	50	95	--
32	blandford	19	157	5'5½	7½	55-55	185	110	50	95	14
33	bock	19	168	5'7½	7½	55-57	190	80	50	95	--
34	kieth	20	155	5'10	7½	52-54	175	85	50	90	--
35	withey	19	147	5'10½	7	46-44	135	95	50	70	10
1	PRUSLIN	19	138	5'7½	7½	43-43	130	75	50	65	10
2	cryderman	19	156	5'8	7	42-42	130	80	50	65	17
3	cornish	18	152	6'	8	50-50	150	75	50	75	--
4	grubel	19	187	6'	8	52-56	180	115	50	90	14
5	sauer	18	171	5'11	8	48-48	150	85	50	75	9
6	keast	18	147	5'9	7½	52-52	170	95	50	85	9
7	logan	20	143	5'10	8	58-58	200	100	50	100	--
8	burns	19	145	5'9	8	50-48	155	55	50	80	--
9	nowak	19	182	6'½	7½	62-66	240	80	50	120	--
10	howell	18	199	6'2½	8½	65-65	245	105	50	125	--
11	arnold	18	168	6'1½	8½	58-58	200	85	50	100	--
12	begley	18	153	5'11	7½	46-44	135	70	50	70	--
13	bauer	18	165	5'10½	7½	56-56	190	85	50	95	--
14	shultis	19	154	5'9	7½	54-56	185	130	50	95	11
15	cousino	19	148	5'9	7	50-50	160	80	50	80	1
16	cline	18	162	5'11	7½	66-66	250	110	50	125	--
17	coxon	19	178	5'11	8	74-78	330	165	50	165	--
18	weber	20	148	5'9	7½	56-52	180	95	50	90	--
19	dykstra	19	157	5'10	8	50-51	160	105	50	80	12
20	peppard	19	145	5'8½	7	56-54	185	115	50	95	8
21	lutz	19	165	5'11¼	7½	66-66	250	100	50	125	--
22	platt	21	170	6'3¼	9	64-64	240	80	50	120	--
23	swartz	20	136	5'7½	7½	52-53	175	75	50	90	--
24	aerts	20	171	6'5	9	63-63	230	105	50	115	--
25	armstrong	20	137	5'10½	8	43-45	130	55	50	65	--
26	barnes	19	154	5'11½	7½	52-56	130	110	50	90	12
27	culver	19	152	6'1	8	72-72	290	105	50	145	--
28	ryan	18	145	5'9	7½	50-48	155	80	50	75	5
29	schmidt	19	156	5'10½	7½	69-67	265	100	50	135	--
30	price	20	194	6'1¼	8	74-80	335	160	50	170	--
31	worth	18	205	5'7¼	7	58-56	195	105	50	100	16
32	brown	18	165	6'¼	8½	60-64	225	90	50	115	--
33	bauman	18	170	6'2¼	8½	54-54	180	100	50	90	4
34	diaz	17	147	5'6	7½	54-54	180	85	50	90	--
35	wallace	19	180	6'1½	8½	73-71	290	80	60	175	--

	NAME	AGE	WEIGHT	HEIGHT	MID-leg LENGTH	TENSION RAW	PULL LBS.	1-RM	10-R.M. %AGE	10-R.M. LBS.	REPS.
1	saidock	25	250	6'4¾	9	66-64	245	100	60	145	--
2	phelps	19	267	6'3¾	9	72-68	280	140	60	170	--
3	piwowar	20	155	5'10¼	7½	52-52	170	90	60	100	--
4	swenson	25	200	5'10½	8	62-64	230	125	60	140	--
5	koechel	18	168	5'11½	8	50-46	150	90	60	90	--
6	cronk	18	166	6'1	8½	73-73	300	125	60	180	--
7	ott	25	150	6'	8	56-58	195	100	60	115	--
8	lukert	18	166	6'2	9	57-57	195	95	60	115	--
9	lumbert	18	153	5'9½	7½	59-57	200	95	60	120	--
10	brown	19	170	5'8	8	73-73	300	135	60	180	--
11	norris	20	138	6'½	8	45-45	135	75	60	80	--
12	haan	18	166	5'10½	7½	66-62	240	105	60	145	--
13	brabb	20	158	5'8	7½	36-36	105	100	60	65	--
14	abel	23	164	5'8½	7½	64-64	240	100	60	145	--
15	till	25	158	5'11½	7½	56-56	190	90	60	115	--
16	theorin	19	146	5'10½	7½	52-54	175	70	60	105	--
17	gulau	19	150	5'11¼	8	46-46	140	95	60	85	6
18	blomquist	18	168	5'11	7½	58-58	200	110	60	120	--
19	laird	19	163	5'10½	7½	56-56	190	90	60	115	--
20	burdick	21	160	6'1½	8½	52-52	170	100	60	100	--
21	terrill	18	139	5'11	7½	46-52	155	80	60	95	--
22	bernd	23	187	6'½	8	50-50	150	80	60	90	--
23	dankenbring	19	189	6'3	7½	62-58	210	120	60	125	--
24	keller	20	179	6'½	8½	48-48	150	90	60	90	1
25	friedman	18	183	6'1	8	52-52	170	75	60	100	--
26	lampel	19	157	5'11	8	49-49	155	75	60	95	--
27	zalar	22	180	6'	7½	56-57	195	130	60	115	7
28	yeoman	20	150	5'5¼	7	50-52	165	85	60	100	--
29	james	20	176	6'½	7½	56-52	210	115	60	125	--
30	nelson	23	149	5'9¼	7½	60-56	200	90	60	120	--
31	brayton	19	131	5'8	7½	52-48	160	90	60	95	--
32	moeke	19	154	6'1	8½	52-50	165	70	60	100	--
33	pendracki	20	179	5'11	8	67-67	260	110	60	155	--
34	kolodzieg	19	177	6'	8½	72-70	285	170	60	170	--
35	long	19	149	5'8	7½	72-74	300	120	60	180	--
1	ELKINS	18	140	5'11	8	54-56	185	75	60	110	--
2	voss	18	176	5'9½	7½	64-64	240	120	60	145	--
3	pitchford	18	181	6'6	8½	57-57	195	85	60	115	--
4	stapelman	19	152	5'11	7½	64-64	240	115	60	145	--
5	berger	19	148	5'9½	8	68-68	245	100	60	160	--
6	cole	20	180	6'3	9½	62-60	220	90	60	130	--
7	hoffman	19	181	5'11¼	7½	74-74	310	100	60	185	--
8	armstrong	18	153	6'	7½	60-62	220	90	60	130	--
9	busch	19	170	6'1½	8½	72-72	290	150	60	175	--
10	rodgers	20	162	5'11¼	8	42-42	125	60	60	75	--
11	hendrikson	18	197	6'1	8	75-76	330	125	60	200	--
12	bott	21	157	5'11½	8	52-54	175	100	60	105	--