A COMPARISON OF THE "OXFORD" AND DELORME TECHNIQUES IN DEVELOPMENT OF THE QUADRICEPS

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by
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ABSTRACT

Title of Study.

A comparison of the "Oxford" and DeLorme Techniques in Development of the Quadriceps.

Statement of the Problem.

To determine the relative effectiveness of the "Oxford" and DeLorme techniques of progressive resistance exercise.

More specifically, the problem was to compare the two techniques in regards: (a) static and dynamic strength, (b) muscle hypertrophy, (c) strength decrement, and (d) cross education effects.

Methodology.

The subjects of this study were eight volunteers, between the ages of eighteen and twenty-six, from physical education service courses at Michigan State University. The static strength of these subjects was determined and the subjects were paired on the basis of static strength scores. The paired subjects were then divided into two groups.

One group exercised strictly according to the DeLorme technique of progressive resistance exercise.

The other group trained strictly according to the Zinovieff, "Oxford Technique". Except for the difference in the administration of these two techniques of resistance exercise, the training program was similar for both groups. The training program consisted of training three days a week, with an alternate day of rest integrated between them, for a period of five weeks. Upon termination of the program, the initial and final scores were analyzed by the student "t" and the differences between the groups were compared.

Conclusions.

(1) Dynamic and static strength are not developed proportionately by P.R.E. (2) Both the DeLorme and "Oxford" techniques develop muscular hypertrophy. (3) No differences were found between the two techniques that can be attributed to causes other than chance.

ACKNOWLEDGEMENTS

The author wishes to express sincere appreciation to his advisor, Dr. Wayne D. Van Huss, for his professional advice, and continual encouragement.

Recognition is also due the subjects who cooperated so faithfully and sacrificed so much of their time to make this study possible.

R. L. D.

DEDICATION

The author wishes to dedicate this thesis to his parents.

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CHAPTER I

INTRODUCTION TO THE PROBLEM

Progressive resistance exercise initially became recognized as a therapeutic method of developing strength in 1944 and as a result of thirteen years of research, it is now conceded to be an excellent method of strength development. This method has been utilized predominately by hospitals and rehabilitation centers in the development and reeducation of atrophied muscle. However, progressive resistance exercises are not limited to therapeutic treatment, but may also be effectively employed as a method for further development of strength in normal symmetrical muscles.

Although it has been established that progressive resistance exercise is an effective technique for developing strength, there remains considerable controversy concerning the most effective training routines. The factors have been scrutinized throughout extensive research programs but the answer still remains beyond our comprehension.

Statement of the Problem.

To determine the relative effectiveness of the "Oxford" and DeLorme techniques of progressive resistance exercise.

More specifically, the problem was to compare the two techniques in regards: (a) static and dynamic strength, (b) muscle by hypertrophy, (c) strength decrement, and (d) cross education effects.

Need for The Study.

For a number of years, research workers have ventured to find the answer to the question -- what method of resistance exercise will produce the most desired results? Since this technique has become so important as a therapeutic agent, obviously it would be extremely beneficial to the patient and the therapist alike, if the most beneficial program could be employed. Before an "ideal" program may be determined, a vast amount of research must be carried on to uncover the many "mysteries" pertinent to muscle development which remain unsolved. The results of this study may only reveal a very small portion of the information needed but the solution can only come from the accumulation and piecing together of data established by similar studies. Thus, it is of the utmost importance that research be carried on continually, in order that a scientific basis may be established for the most efficient administration of resistance exercises.

Limitations.

1. The most critical limitations were of a psychological nature. One of these was concerned with the motivation of the subjects and the other being the fact that all the subjects were not inured to the physical discomforts associated with vigorous exercise.

2. The inadequate number of subjects participating was a definite limitation but this situation was unavoidable.

3. The daily activity of each subject was an uncontrollable factor.

4. The technique for measuring hypertrophy proved to be inadequate.

Terminology.

P.R.E. - A load-resisting knee extension exercise employing the use of a metal boot with adjustable weights to create the resistance.

One R.M. - The maximum weight that can be lifted through a 90 degree range of motion to complete one repitition.

Ten R.M. - The maximum weight that can be lifted through a 90 degree range of motion to complete ten repetitions.

Tensiometer* - An instrument used to measure the amount of tension applied to a cable.

Volumometer. - An instrument used to measure leg volume by means of water displacement.

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

CHAPTER II

REVIEW OF LITERATURE

Introduction to the Two Techniques of Exercise

The principle of the DeLorme technique of P.R.E. is that of starting with a light load and systematically increasing to the maximum load for ten repetitions. The program consists of three bouts of exercise, with each bout composed of ten repetitions -- a total of thirty repetitions. DeLorme and Watkins[1] state that the initial bout should be executed with a load equalling one-half the ten R.M. The load of the second bout should consist of three-quarters of the ten R.M. and the final bout of ten repetitions should be executed with the total ten R.M.

The exercise program to be compared with DeLorme's method is known as the Zinovieff "Oxford Technique". The theories of these two proponents are antithetic. The principle of the "Oxford Technique" is that the individual starts each exercise period with his ten R.M. and after each bout of ten repetitions, the weight is reduced. The purpose of the gradual reduction is to compensate for the fatigue which the individual experiences, thus allowing him, with the lighter load, to complete the entire ten repetitions of each successive bout. This technique consists of a total of one hundred repetitions -- ten bouts of ten repetitions each. Zinovieff believes that an individual must exercise at maximal exertion in order to develop strength.

<u>DeLorme Technique.</u>

This technique of P.R.E. was developed in 1948 by DeLorme and Watkins, and since has become the most popular method in clinics and physical therapy departments throughout the country.

To justify the procedure of their exercise program, DeLorme and Watkins[2] state that the first two bouts of an underload nature are necessary to prepare the physiological state of the individual prior to the maximum exertion. They observe that it has been demonstrated through clinical treatment that one bout of ten repetitions at a maximum effort is sufficient for the optimum development of strength. The authors base this theory on the fact that weight lifters have developed a great deal of power through use of the same routine. The purpose of the initial two bouts is not entirely clear since they assert that there has been no evidence presented, suggesting that this type of exercise causes trauma to muscle fibers regardless of the severity of the effort. Tension develops too slowly to produce muscle tears. The administration of the initial two bouts is for some physiological reason. There is a possibility though that the ligaments, tendons, and joints are susceptible to injury from a very heavy weight.[3]

McGovern and Luscombe[4] criticized the DeLorme technique because they claim that due to the fatigue factor, many individuals cannot complete the thirty repetitions. This is especially true among poliomyelitis patients; however, it has also been noted that this phenomenon is not related solely to weak muscles since muscles graded as ninety-five per cent, seventy-five or eighty per cent also were unable to complete the thirty repetitions. However, these authors reported that a comparison between the DeLorme technique and their modified DeLorme technique revealed a "t" value of 0.242 which was of no statistical significance. Zinovieff[5] also reports that early onset of fatigue inhibited an individual's performance, due to the fact that he could not extend his knee completely each time.

Hellebrandt and Houtz[6] report that the only evidence to support the DeLorme technique is that obtained from clinics -- there is no scientific justification. This technique was developed during World War II and was utilized in military hospitals and consequently was only a small part of the rehabilitation program which also included reconditioning exercises, various athletic programs, and occupational therapy. For this reason, the technique was acceptable since the patients received a sufficient amount of exercise. The majority of the civilian hospitals employing this technique, however, do not offer additional training programs. The expediency of administration was probably the primary factor in its growth and popularity. Hellebrandt and Houtz[7] reveal that two subjects participating in the DeLorme technique, using a twenty-five R.M., improved their mean strength by 33.35 per cent over a training period of fifteen days -- this was not significant as compared with the Illinois underload and overload techniques. They have accumulated evidence which suggests that:

> The human machine operates under such wide margins of safety that it is difficult to deplete hidden reserves of power in short periods of exercise consisting of a small number of contractions.

Capen[8] reviews comparisons of the DeLorme technique with three modifications of the same. Two of these comparisons resulted in no significant difference in strength gained, but the third method proved to be slightly superior to the DeLorme method. The technique that was superior consisted of five sets of repetitions in which the subject executed as many repetitions as possible each time.

Oxford Technique.

This technique was originated in 1951 by A. N. Zinovieff, a physiatrist at the United Oxford Hospitals. After contending with several problems in administering the DeLorme technique of P.R.E., Zinovieff devised the "Oxford Technique" which is based on the theory that an individual should exercise against an equivalent of maximum resistance at all times.

Zinovieff[9] reports that in administering this technique to several patients with various knee injuries, the average increase in volume was three-eights of an inch every 2½ weeks and that absolute power, as measured by a single spring lift, increased by ten pounds a week. The patients were discharged on an average of just over two weeks of treatment with normal, or nearly normal power -- nearly normal power was defined as being within ten pounds of the normal quadriceps. Zinovieff[10] recognizes that one great practical difficulty lies in the estimation of the amount of weight to be deducted after each bout. He estimates that a one pound reduction was found to be average.

McGovern and Luscombe[11] experimented with a modification of the "Oxford Technique" and found that their results equal those obtained from the "Oxford Technique". This modification consisted of a total of thirty repetitions instead of the advocated one-hundred. In experimenting with poliomyelitis patients, these authors discovered the patients could complete the "Oxford Technique" whereas they couldn't accomplish the DeLorme method of P.R.E. Hellebrandt and Houtz[12] also experimented with this same modified method but they reported no significant increase in strength.

McMorris and Elkins[13] compared the effects upon strength of a modified DeLorme technique with a modified Zinovieff technique after a twelve week exercise period. The procedure for the DeLorme technique consisted of four bouts of ten repetitions starting with one-quarter, one-half, three-quarters, and then the total. The Zinovieff method was composed of the same groups of repetitons only they were executed in reverse order. The results showed that the Zinovieff group increased their ten R.M. 5.5 per cent more than the DeLorme technique. Graphical data shows the increase for each group was gradual, but after eleven weeks, the Zinovieff group rises sharply.

Hellebrandt and Houtz[14] studied the effects of the original "Oxford Technique", with the exception that there were twenty-five repetitions instead of ten, on the development of strength. One weakness of this study was that only one subject participated. The results disclosed an increase in strength of 124.61 per cent over a period of nine training days, at which point the experiment was discontinued because the exercise became so severe. The authors feel that the subject's ability to withstand stress was the principle reason why he achieved such a vast increase in strength so quickly.

There is some controversy and surely a degree of hesitation among the patients to exert a maximal effort with only a very short warm-up period. In regards to this observed reluctance, Granit[15] has pointed out that the human body contains an inhibitor that protects the muscles against traumatizing degrees of tension. Thus, the evidence suggests that a muscle cannot be injured by volitional effort when the range of motion and cadence are controlled.

Strength.

Dynamic. Due to the vast interest in strength development, there have been several excellent studies completed in regards to dynamic strength. As a result of this research, many research workers hypothesize that strength is the outgrowth of the over-load principle. Steinhaus[16] stated, "a muscle develops in size and strength only as it is over-loaded, that is, as it is required to exert force against greater resistance than it normally does". Some of the other advocates of the overload principle are DeLorme and Watkins[17] , and Hellebrandt and

Foutz[18] . A study characteristic of the underload performance and excessive repetitions revealed gains in strength of around 9.88 per cent. In the same series of studies, strength gained through overload principles ranged from 123.36 per cent to 208.20 per cent. Exercising to physiological degrees of fatigue are not contraindicated if there are no cardio-vascular-respiratory defects and the general health is unimpaired.[19]

Steinhaus[20] theorizes that strength is, in part, learned, which he bases on unusual feats of strength that are often performed by individuals under hypnosis or overly excited. DeLorme, Ferris, and Gallagher are also advocates of the learning theory. For example, in a recent experiment they didn't attempt to determine the individual's one R.M. until he had been exercising a week -- allowing for motor learning.[21]

Mathews and Kruse studied the effect of frequency of exercise and resistance on strength and their findings suggest that by increasing the frequency, a more significant gain in isotonic strength is attained. However, regardless of frequency, individuals reacted in a manner peculiar to themselves. The authors concluded that one load may not be sufficient for all subjects.[22]

In regards to development of strength after surgery, DeLorme and Watkins[23] assert that within an average period of six weeks, the individual will have recovered the normal strength of the quadriceps femoris. Generally, the longer that exercises are continued, the smaller will be the gain in strength as very often strength may be doubled within the first month or two of exercise and then gradually taper off.[24]

Once strength is attained, DeLorme and Watkins found that little or no reductions have occured in athletes for a period of one year after the P.R.E. program was discontinued.[25] Possibly after developing strength, athletics will afford enough exercise to maintain that level. This assumption may not hold true if reversed, since DeLorme and Watkins[26] found that athletics of the most strenuous variety would not produce the same degree of strength as P.R.E. This has been exemplified in the quadriceps femoris development of football players and trackmen with several years of competition -- some have been able to increase their strength from fifty to one-hundred per cent within six to eight weeks. Houtz et al.[27] believe that after a period of time equal to the exercise period, there will be no appreciable reduction in muscular strength. Abramson[28] found that evidence of strength gained in a training period was still maintained, though considerably reduced, after a lapse of one year. Gallagher and DeLorme found no loss of ability to lift weight by one R.M. measurements of the quadriceps muscle in seventeen adolescent boys, two to twelve months after the convalescent period.[29]

Static. Baer, et al. declare that it is readily apparent that neither total work done nor power, in the physical sense, is a major factor in determining the improvement of isometric tension after exercise programs. To defend their declaration, they report that upon completion of experiments on isometric strength they obtained marked and significant increases in static strength in two weeks by a program of high resistance exercises at a rate of ten contractions per minute. A program with an increased speed of thirty contractions per minute disclosed no significant effect.[30] A. V. Hill vindicates this theory with the following statement;

> the more rapidly a muscle shortens, the more potential energy developed in it on stimulation is wasted in the passive and viscous processes associated with the change of form.[31]

Also in accord with this, Wilkie[32] states that tension decreases as the speed of contraction decreases.

Hettinger and Muller[33] studied the effects of static strength and report that one practice period per day in which a steady contraction was held for six seconds, resulted in as much increase in strength as longer periods of muscle contraction and more frequent practices. Muscle strength increased more rapidly with a load of two-thirds maximal strength but beyond this point, load had no effect. They postulate that the oxygen deficit of the muscles is a factor of strength development. In relation to this postulation, DeLorme and Watkins[34] theorize that even though P.R.E. is a dynamic movement, there may possibly be enough tension developed and the rate of exercise so slow that it exemplifies a static contraction and nullifies the usual stimulating effects of dynamic exercise on the circulation. Perhaps there is a relationship between static contractions and the oxygen deficit theory -- it deserves a great deal of consideration. Wolbers and Sills[35] studied the effects of static contractions on high school boys and revealed that contractions of six seconds duration produced significant gains in strength.

Siebert[36] found that by stimulating one leg of several frogs isometrically, and the other leg isotonically for fourteen days, the muscles that were contracted isometrically were thirteen per cent heavier than those contracted isotonically. He relates that this extra weight is due to hypertrophy and it is generally believed that hypertrophy is related to strength.

In a comparison of isotonic and isometric contractions, a study by Mathews and Kruse[37] postulates that isometric contractions result in greater strength gains than does the isotonic type of contractions in terms of exercises used in the study.

Also in relation to development of static strength, Ouellette[38] and Berger[39] have found that programs of P.R.E. have significantly increased dynamic strength but have had no significant effects on static strength. The cause of this phenomenon could not be explained and at present, still remains to be an unsolved mystery.

Hypertrophy.

McMorris and Elkins[40] define muscular hypertrophy as an increase in the circumference of muscle fibers -- beyond normal. DeLorme and Watkins[41] attribute the fiber development to an increasing amount of connective tissue, thickening of the sarcolemma, increase in the number of capillaries and muscle hemoglobin, phosphocreatine, and glycogen, whereas Steinhaus[42] attributes it largely to the sarcoplasm.

Siebert[43] has studied methods of developing hypertrophy and through animal experiments has found that is appears only when the rate of working is increased. The mere repetition of an activity is not conclusive to development of hypertrophy of skeletal muscles. Power is the decisive factor and not the total amount of work done. Kohlrausch[44] has studied this same problem with dogs and reveals that hypertrophy is a function of the amount of work performed in a unit of time.

The measurement of hypertrophy has been one of the most problematical issues encountered in this field by research workers. DeLorme, Ferris, and Gallagher[45] express that in their opinion, measurement of hypertrophy in the laboratory is far from being easy and under clinical conditions it is much more difficult. In situations where microscopic measurement is impossible, McMorris and Elkins[46] feel that hypertrophy must be measured through the use of volumetric studies, calipers, or circumferential tape measurements. Dr. Ray Piaskoski relates that the fallacy of using tape for circumferential measures is reliable only if the same observer can duplicate the tension of the tape each time. In regards to tape measurements, Hrdlicka[47] recommends a linen tape as being easier to handle, but McCloy[48] reports that linen tapes are unsatisfactory because of shrinkage. In twenty duplicate arm measurements with the tape drawn to optimal tension, McMorris and Elkins report a mean difference of .08 ± .07 cm. and with the tape loosely applied, .06 ± .05 cm. was obtained. Neither of the differences were statistically significant.

The history of volumometer measurement dates back to 1814 when John Robertson experimented with it in connection with specific gravity. After a lapse of one

hundred years, Spivak[50] renewed the possibilities of volumetric testing because he felt the need for a technique that would measure redistribution of bulk. Sometimes the concentration of bulk may shift from one position to another and if this is the case, ordinary procedures of measurement do not allow for this redistribution of bulk. Theoretically, the principle of the volumometer is feasible but to the knowledge of this author, there is no evidence in the literature to support the reliability of this instrument.

The reason why hypertrophy is so difficult to measure is because there are so many variables. Some of these are: (1) amount of subcutaneous tissue, (2) the state of hydration, (3) the amount of vasodilation, (4) the state of development of other included muscles, and (5) the muscle length.[51] As muscular hypertrophy is developed, many authorities assert that strength is also developed. Some of the factors that influence hypertrophy and power are: (1) available joint range for exercise, (2) degree of motor learning deterioration, (3) pain, (4) willingness and ability of the person to exert maximal volitional effort.[52] DeLorme and Watkins[53] through clinical experience believe that both are developed synonymously. The circumference of a normal arm or thigh can be increased an inch or more through a few weeks of exercise. This is attained by exercising with heavier weights and fewer repetitions. Clarke[54] reports a correlation between girth and the McCloy arm strength score of .73. Rorick and Thompson[55] studied the relationship of size and strength among fifty-one seven year old children by means of roentgenographic measures. The correlations reported between ankle extensor strength and measures of muscle size ranged from .58 to .63 for the boys. The correlations for the girls were all under .52 but this was attributed to the greater homogeneity of the girls scores. McMorris and Elkins[56] correlated mean gains in girth with mean gains in strength of twelve subjects after an exercise period of twelve weeks and found no significant correlation.

Frequently, in rehabilitation programs, strength of the atrophied quadriceps muscle is restored to normal before normal muscle volume is regained. This fact may seem insignificant but DeLorme and Watkins[57] have observed that in cases such as this, the strength often deteriorates more rapidly than in cases where the volume has also attained normalcy. Major J. W. Schaeffer confirms this and also states that readmission of men to the hospital was greater among the individuals who did not regain normal muscle volume.[58] If these observations are authentic, then therapists in rehabilitation should strive for this more definite goal -- restoration of normal muscle volume as well as strength and efficiency of contraction.

Concerning the rate at which hypertrophy can be developed, a study related that among eighty patients, thigh circumference could not be restored to normal in a period of three weeks. This indicates that improving the efficiency of quadriceps, contraction may increase strength without a proportionate increase in muscular hypertrophy.[59]

There has been evidence presented that during periods of rapid growth in body length, exercise does not affect muscle growth as much as when the tendency toward growth is in diameter. Another study of college students disclosed that the "asthenic type" individuals respond the least while average sized individuals showed the greatest improvements in muscle girth.[60]

Strength Decrement.

Strength decrement is the effect of fatiguing a muscle to the point that its ability to apply muscular strength is reduced.[61] Steinhaus postulates that the postponement of fatigue is related to the ability of an organism to balance catabolic with appropriate anabolic processes. Basically, this means a sufficient supply of oxygen, and an adequate food supply.[62]

Some of the more evident causes of fatigue are: (1) depletion of phosphocreatine store as by loss of one or both of its breakdown products, (2) failure of the resynthesis process due to (3) inability to oxidize lactic acid promptly due to the shortage of oxygen. The lactic acid then accumulates in the circulatory system and causes, (4) disturbances in the carbon dioxide carrying power of the blood, in the respiratory center and in the vasomoter regulation which an increased circulation can only temporarily compensate, and (5) failure of the circulatory and respiratory system to meet these demands.[63]

Due to the apparent lack of research concerning strength decrement, Clarke et al.[64] proceeded to study the effects of exhaustive muscular exercise on the elbow flexor muscles. The subjects exercised once a week for six weeks on the Kelso-Hellebrandt ergography. Ergography was performed in accordance with the technics described by Clarke.[65] The results of the study revealed a decrement in strength of twenty-nine to thirty-three per cent in thirty seconds after exercise but after about two hours, the trained subjects were only five to ten per cent below their pre-exercise level, while the untrained subjects were nineteen to twenty-five per cent below their pre-exercise level. This evidence suggests that muscular training will develop a degree of endurance which will afford a faster recovery rate after exercise.

Tuttle et al.[66] investigated the relationship between strength and endurance involving the back and leg muscles for the comparison. They constructed a dynamometer that would measure strength and endurance especially for this experiment. The results of this study were: (1) individuals with a greater maximum strength have a greater strength endurance index, (2) stronger individuals can maintain a smaller proportion of their maximum strength, and (3) the development of strength endurance is not directly proportional with the development of strength.

Holck[67] conducted a long term experiment in an effort to study the improvement of endurance over a period of 4½ years. The forearm flexors were the muscles exercised and the Mosso type ergograph was the instrument used to measure the endurance. Continuous improvement in endurance was noted over a period of several years reaching a high point equal to five-hundred per cent of the original endurance after 4½ years. In another study an endurance improvement, Hedvall reported an increase of 819 per cent in fifty days of training the arms on the Johnson ergograph. Within two months after cessation

of daily training, the level of endurance had fallen to one-third of the maximum attained in training.[68]

Baer et al.[69] experimented with various methods of isotonic and isometric exercise programs and they found a significant increase in endurance in all programs but no specific one had a more significant effect than any other. This would possibly be attributed to the fact that none of them exceeded twenty contractions. In regards to the number of contractions necessary to develop endurance, DeLorme and Watkins[70] relate that high repetition and low resistance exercises are desirable in order to provide maximal increase in work capacity. Maison and Broeker[71] studied this same problem and from their results they postulate that endurance for working with heavier loads may best be developed by a great deal of practice with lighter loads. After analyzing the results, they feel that training is due largely to improvement in the nervous direction and vascular supply.

Cross Education.

The phenomenon of cross transfer of strength from the exercised ipsilateral limb to the unexercised contralateral limb was reported in the literature as far back as 1894. Even though this transfer of strength has been evident for so long, the reason for this peculiarity is still unsolved. In fact, it hasn't received too much attention until just recently.

Scripture et al.[72] reported the cross transfer of strength from one limb to the other in 1894. A mercury dynamometer which consisted of a rubber bulb attached to a glass tube containing mercury was the instrument used for exercising the subjects. The effects were recorded in inches and after nine exercise bouts, the bulb pressure for the right hand increased from 28.8 to 48.6 inches. The unexercised left hand increased from 29.6 to 42.3 inches, which indicates cross transfer of strength. Slater-Hammel administered a systematic exercise program of weight lifting involving the flexion and extension of one arm and found a positive and significant improvement in the muscular performance of the other arm. This study also revealed that the bilateral gains were rapidly lost after cessation of exercise.[73]

Clarke et al.[74] and Mathews et al.[75] experimented with ergographic exercises to determine the relationship between cross transfer of strength and endurance on the exercised and unexercised arm. The results of both studies revealed a significant increase in muscular strength in the ipsilateral and contralateral limbs. The development of endurance in the ipsilateral limb was statistically significant but there was no significant increase of endurance in the unexercised arm. Hellebrandt

et al.[76] found through experimenting with restive exercises that there was also a cross transfer of strength.

All the research in this area conclusively agree that there is a cross transfer of strength but as yet, there is no significant evidence to substantiate the cross transfer of endurance.

Wissler and Richardson[77] postulate that this phenomenon is due to the diffusion of motor impulses in the spinal cord which consequently radiate to the contralateral limb. Another theory suggests that cross transfer results from synergistic fixations of the contralateral musculature. The tensing or fixation of the opposite muscles caused by exertion of the exercised muscle group results in increased strength of the unexercised muscles.[78] A possible assumption might be that the fixation of muscles of the contralateral limb could be a form of static contraction. Several studies have shown that static contractions produce significant increases in strength and Hettinger and Muller[79] have found that only from one-third to two-thirds maximum effort needs to be exerted -- which would probably be about all the contralateral limb would exert.

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CHAPTER III

Methodology

Introduction.

This study was conducted in an endeavor to evaluate the DeLorme technique of P.R.E. as compared with Zinovieff's "Oxford Technique" of heavy resistance exercise in regards to static and dynamic strength, strength decrement, hypertrophy, and cross education. The subjects who participated in this experiment were volunteer male students from physical education service courses at Michigan State University. These subjects were equally divided into two groups and each group participated in a training program for a period of five weeks.

Due to the many measurements necessary, various instruments were employed. The instruments used and the measurements recorded were as follows: (1) one R.M. to measure dynamic strength, (2) cable tensiometer to measure static strength, strength decrement, and cross education, (3) the frictional bicycle ergometer as an instrument on which work could be standardized, and (4) the volumometer to measure hypertrophy.

Experimental Design.

Eight subjects with normal knees, ranging in age from eighteen to twenty-six years, were selected from physical education service courses at Michigan State University. The subjects were matched on static strength and divided into two groups. Prior to commencement of the five week training period, initial measurements were collected (T_1) to determine static and dynamic strength, strength decrement, thigh girth, and the static strength of the contralateral limb. Upon termination of the training period, measurements identical to the initial measurements were again administered (T_2) and the differences in the data analyzed.

Programs of Training.

The exercise performed by all eight subjects was knee extension of the right leg. The position the subject assumed was identical to the position recommended by Clarke[1] for testing quadriceps strength, with the exceptions that in performing the exercise the subject in this study moved his leg through a 90 degree range of motion -- from 90 to 180 degrees. A three inch pad was placed under the femur just proximal to the knee joint for the purpose of providing comfort and to keep the femur parallel to the floor. (Fig. I) The cadence of of the contraction to full extension and return to 90 degrees flexion was controlled by a metronome. One complete repetition was performed in six seconds -- three seconds to contract and three seconds to return to the starting position -- and a bout of ten repetitions was completed in one minute. Upon execution of one bout, all the subjects rested for one minute before commencing the next bout. The rest pause was equal in duration to the exercise period. A counter was utilized to record the repetitions. An Eastman Kodak timer was used in all situations where time was a critical factor. All subjects exercised three days per week, integrated with an alternate day of rest, for a period of five weeks.

The four subjects comprising the DeLorme group performed three bouts of ten repetitions each day of exercise. The first bout consisted of a weight equal to one-half of each individual's ten R.M. The second bout was executed with a weight equal to three-quarters the subject's ten R.M. and the final bout was executed with the individual's total weight for ten R.M.

The four subjects that made up the Zinovieff group performed ten bouts of ten repetitions -- a total of one hundred repetitions each day of exercise. Before proceeding to exercise with the maximal load, each subject performed ten anti-gravity knee extensions as a general warm-up. Each subject executed the first bout with his ten R.M. and each of the nine successive bouts were performed with a lighter load than the preceeding bout but with a load which was still considered to be the individual's maximum -- allowing for the degree of fatigue due to the muscular exertion. It was impossible to reduce the weight systematically after each bout and still maintain a maximum effort on the suceeding bout, especially on a day when the ten R.M. was increased. The maximum effort was maintained by the subjective observation of the experimentor because there is no objective technique which insures maintenance of maximal effort. The amount of variation of an individual from day to day is another factor to be confronted.

Basically, the ten R.M. for the subjects of both groups was determined in the same manner -- seventy per cent of each individual's one R.M. was arbitrarily chosen as the starting point. From here, through trial and error, adjustments were made to determine the individual's true ten R.M. The method of increasing the ten R.M. of each subject was also based on the subjective judgement of the experimentor. Upon completion of the ten R.M., the subject was asked if he thought he could have done a few more repetitions. Muscle tremors, facial grimaces, and other apparent overt physical signs indicative of stress were observed by the experimentor in an effort to determine whether the subject was putting forth maximal exertion. Because of the hypothesis of this study it was necessary that the individual extend his leg completely each time and to determine complete extension, a guide was employed. (Fig. I) Each subject was instructed to touch the projecting portion of the guide each time and if he couldn't do it, the weights were adjusted accordingly in order that this aim could be fulfilled. If, through these observations, it was evident that the subject could increase his ten R.M., additional weight was added the next day of exercise.

Testing Technique.

Static Strength. The static strength of each individual was measured by the cable-tensiometer using the technique suggested by Clarke[2] with the exception that the weight of the leg was not taken into consideration. The static strength of each subject for the initial and final tests was recorded as the average of two tensiometer scores.

The author of this study obtained a .91 coefficient of reliability for the tensiometer by the test-retest technique.

Dynamic Strength. The dynamic strength for each individual was recorded as the maximum amount of weight that could be lifted for one repetition, by knee extension.

Strength Decrement. This was obtained by measuring the static strength of each subject before he exercised on the ergometer and again thirty seconds afterwards. The difference between these measurements was considered to be the decrement. This particular time duration was chosen in view of a study by Clarke et al.,[3] which they found the greatest decrement to be thirty seconds after exercise. A duration of time less than thirty seconds may have been more effective but enough time had to be allotted for positioning the subject. The exerted effort on the ergometer was a rate of speed of twenty miles per hour, 6½ pounds resistance, and for a period of time only as long as the particular rate of speed was maintained. The speed was recorded by a speedometer and the revolutions completed by the left foot were recorded by means of an automatic counter.

Instructions employed in regards to the use of the frictional bicycle ergometer were those suggested by Karpovich.[4]

Muscle Hypertrophy. The volumometer was used to determine the girth of each subject's leg. (Figure II). The tank was thirty-five inches high and 13½ inches in diameter. One of the two water outlets was 29¾ inches from the bottom and had an open-close attachment which was used in standardizing the level of the water. The other outlet was an overflow opening, thirty-three inches from the bottom, through which the water was displaced for measurement. The purpose of both outlets was to eliminate almost two gallons of water from the measurement. It was estimated so that the smallest leg probably measured would at least displace a small quantity of water. By obtaining this smaller quantity of water, the measurements were more accurate. Both outlets were coated on the inside with the paraffin wax to precipitate the displacement of water. When filling the tank, the standardizing valve was left open and when water started flowing from it, the inflow of water into the tank was discontinued. When the water stopped dripping from this valve, it was closed and the tank was ready for use. Before entering the tank, each subject was instructed to stand flat footed with all his weight on the right leg, to keep his leg straight, to avoid contracting his quadriceps, and to remain as motionless as possible. When the measurement was ready to be taken, the subject stood on an eighteen inch stool which was alongside the tank. He then stood on his left leg and slowly lowered his right leg into the tank, keeping his heel along the inside of the tank. After getting into the tank he was permitted to rest his buttocks against the back of the tank. The displaced water was then collected in a 3000 millileter beaker and weighed on a balance scale in grams.

The coefficient of reliability for this instrument was .21.

Cross Education. The development of strength in the contralateral limb was measured by the cable-tensiometer.

Statistical Technique. The student "t"[5] was the statistical technique used to analyze the differences between the DeLorme and Zinovieff groups and the differences within the groups in regards to all tests administered.

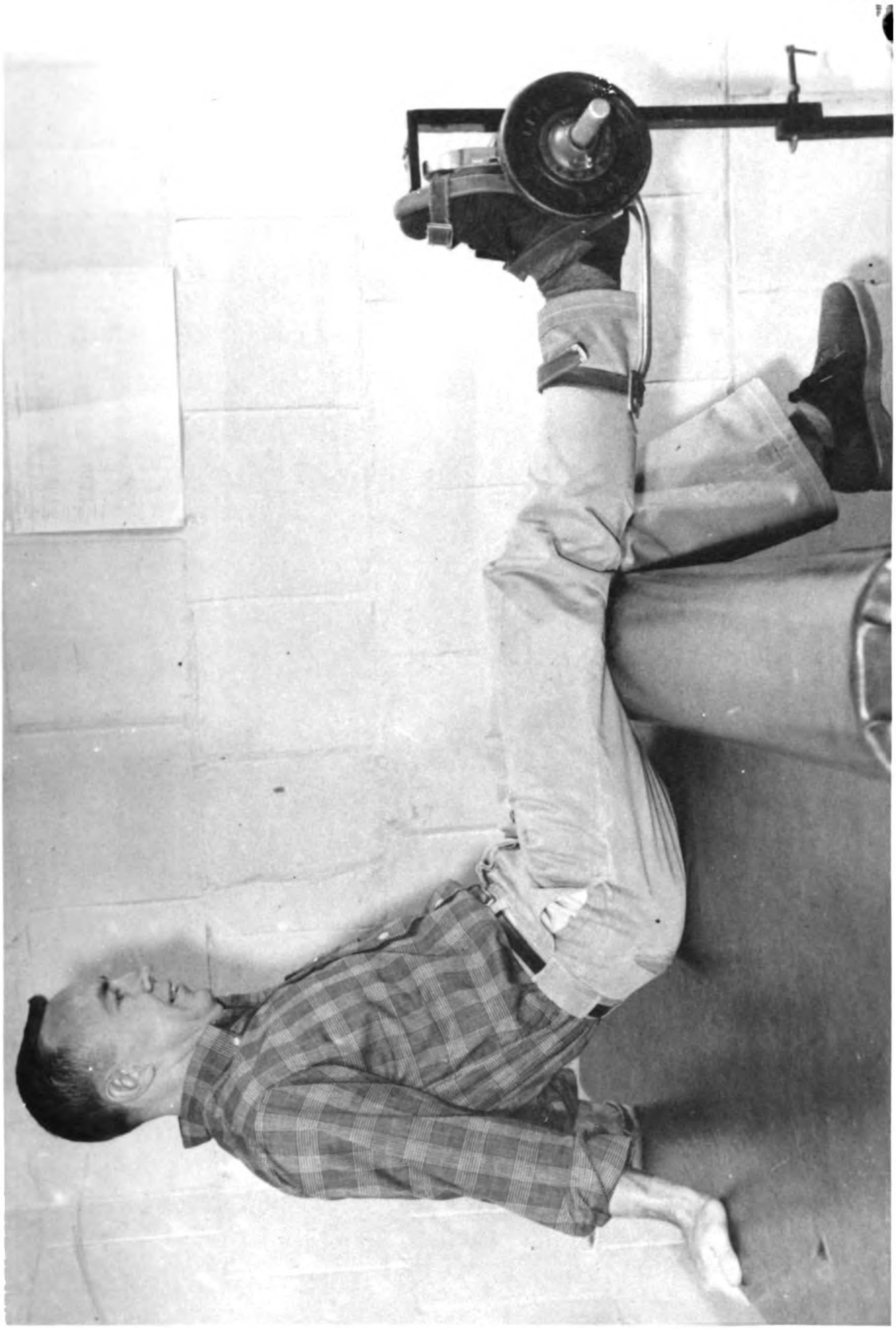

Figure I
Position for the Execution of a Repetition

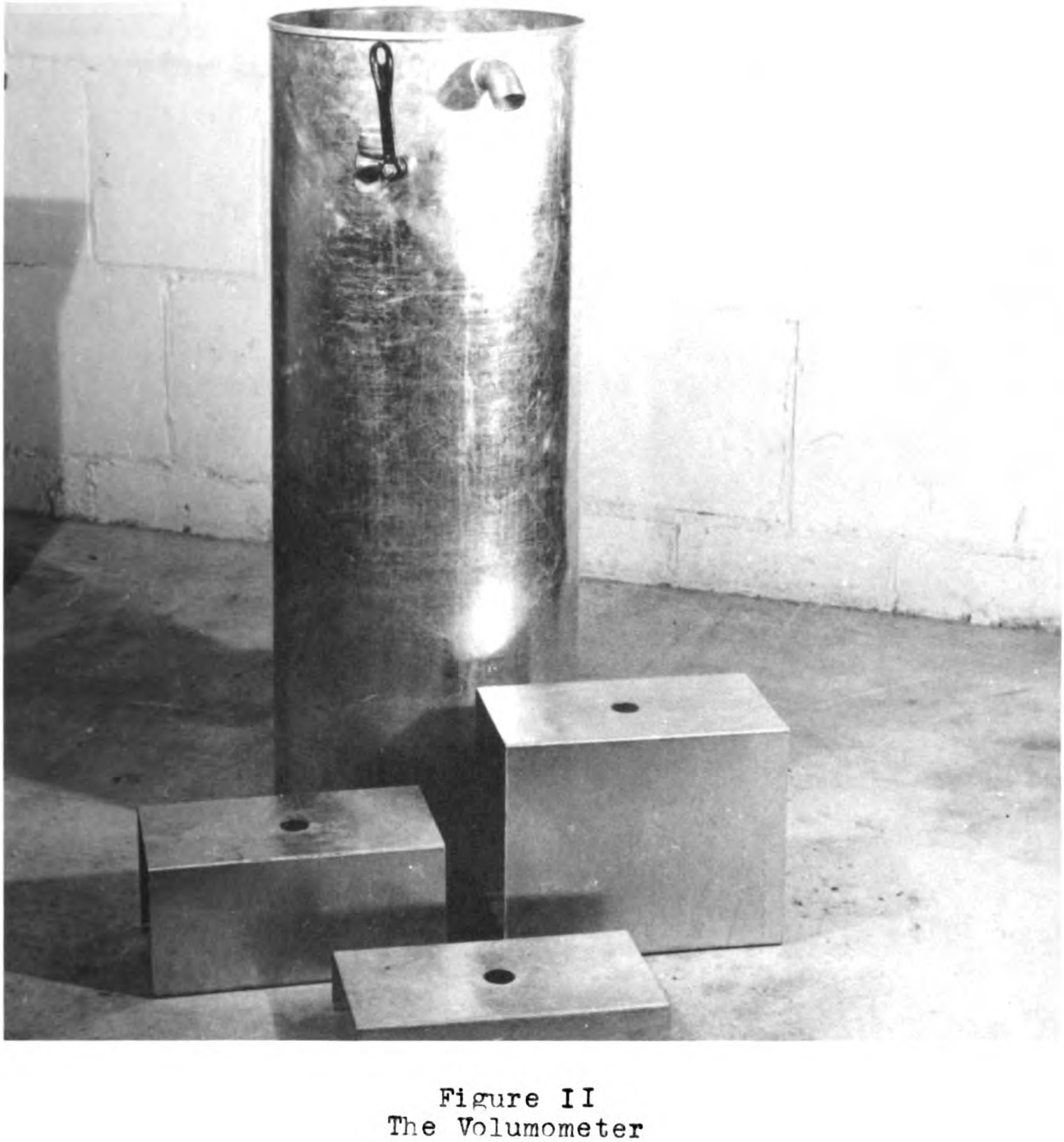

Figure II
The Volumometer

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CHAPTER IV

ANALYSIS OF DATA

The present study was undertaken as a comparison between DeLorme's Progressive Resistance Exercise technique , and Zinovieff's "Oxford Method" in regards to their effect on static and dynamic strength, hypertrophy, strength decrement, and cross education. The purpose of this analysis was to determine whether either of these training programs would produce greater improvements than the other.

Analysis of Data.

Static Strength. An analysis of the T_1 and T_2 scores show that neither the DeLorme group nor the Zinovieff group produce statistically significant results in the ipsilateral limb; however, every subject in both groups increased his static strength from T_1 to T_2 . (Table I). The "Oxford" group showed the greatest mean improvement (Table II), but the difference between the two groups was not statistically significant.

Since the "Oxford Technique" produced a greater mean difference from T_1 to T_2 (Table II), the results of this study support the results of previous studies[1,2] that have shown a positive relationship between static strength development with an increasing number of repetitions.

Dynamic Strength. The DeLorme group improved their dynamic strength (1 R.M.) to a degree that was statistically significant at the five per cent level of significance. (Table I). One of the subjects improved over one hundred per cent while another came very close to that degree in the fifteen days of training. The subjects in the "Oxford" group did not increase their strength significantly, (Table I) although one individual also increased his dynamic strength by over one hundred per cent. Another came very close to this degree of improvement. One subject however, increased his dynamic strength by only five pounds.

The DeLorme group showed the greater mean improvement (Table II) but the mean differences between the groups were not significant. Since the mean difference of the DeLorme group was the greater, even though only slightly, than the "Oxford" group, these results tend to agree with the evidence suggested by other studies[1,2] that there is a positive relationship between the development of dynamic strength and exercises consisting of fewer repetitions.

Hypertrophy. The difference between the T_1 and T_2 scores of the DeLorme group were found to be statistically significant beyond the five per cent level of significance. (Table I). Analysis of the T_1 and T_2 scores of the Zinovieff group reveal the difference was significant beyond the one per cent level of significance. (Table I).

Analysis of the T_1 and T_2 differences of each individual in both groups reveals that in every case the T_2 score was greater than the T_1 score. A comparison of the T_1 and T_2 differences of the two groups revealed no statistically significant differences. (Table II).

Strength Decrement. Statistical analysis of the decrement of the DeLorme group showed no statistical significance between the T_1 and T_2 scores. (Table I). The mean difference between the T_1 and T_2 scores of the "Oxford" group also was of no statistical difference. (Table I). The mean differences of each group were also analyzed and were found to be statistically insignificant. (Table II).

Cross Education. Analysis of the T_1 and T_2 scores of the DeLorme group reveal a statistically significant development of static strength in the contralateral limb beyond the five per cent level. (Table I). The "Oxford Technique" did not produce a statistically significant development in strength of the contralateral limb. (Table I). A comparison of the mean differences of the two groups was not statistically significant. (Table II).

TABLE I

Initial to Final Test Results

DeLorme	Mean T_1	Mean T_2	t	P %
Static strength	254.38	318.75	2.61	10
One R.M.	60.00	96.25	5.32	5
Hypertrophy	3872.95	4175.13	3.23	5
Strength Decrement	1.88	-55.63	2.05	20
Cross Education	230.00	270.00	3.57	5

Oxford	Mean T_1	Mean T_2	t	P %
Static strength	255.00	341.88	2.33	20
One R.M.	66.25	101.88	3.05	10
Hypertrophy	3369.44	3535.13	6.24	1
Strength Decrement	-10.00	-125.00	.77	50
Cross Education	238.75	296.25	1.57	30

TABLE II

Comparison of DeLorme and Zinovieff

Methods of P.R.E.

	DeLorme Mean Difference T_1-T_2	Zinovieff Mean Difference T_1-T_2	t	P %
Static Strength	64.25	86.88	.25	80
One R.M.	36.25	35.63	2.52	10
Hypertrophy	302.18	165.69	.63	60
Strength Decrement	-57.5	-21.25	.99	40
Cross Education	42.50	57.50	1.03	40

CHAPTER V

SUMMARY, CONCLUSIONS and RECOMMENDATIONS

Summary.

The subjects for this study were eight volunteer male students from the physical education service courses at Michigan State University. The subjects were matched on static strength and then the pairs were divided into two groups. One group trained strictly according to the DeLorme technique of progressive exercise while the other group trained according to the Zinovieff, "Oxford, technique" of resistance exercise. The training program consisted of three exercise days per week, integrated with a day of rest, for a period of five weeks. The purpose of this study was to compare these two techniques of progressive resistance exercise in an effort to determine their affect on static and dynamic strength, hypertrophy, strength decrement, and cross education.

Conclusions.

1. Dynamic and static strength are not developed proportionately by P.R.E.

2. Both the DeLorme and "Oxford" techniques develop muscular hypertrophy.

3. No differences were found between the two techniques that can be attributed to causes other than chance.

Recommendations.

1. Further experimentation with the volumometer as instrument to measure muscular hypertrophy.

2. The need for more extensive research in regards to the relationship between static and dynamic strength.

3. Further research in regards to the relative development of strength and muscular endurance.

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APPENDIX

MICHIGAN STATE UNIVERSITY
DEPARTMENT OF HEALTH, PHYSICAL EDUCATION, AND RECREATION

GRADUATE STUDIES AND RESEARCH

TABULATION SHEET

TOPIC: TABULATION OF RAW SCORES

DATE OF TABULATION: May 1957

TABULATED BY: Richard L. Durrant

Training Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		Total Increase			
DeLorme																				
P.G.	50	50-	52.5	55	55	57.5	57.5	57.5	57.5	60	60	62.5	65	67.5	75		25			
D.O.	30	30	30	30	32.5	32.5	35	37.5	37.5	40	40	42.5	45	45	50		20			
S.W.	37.5	37.5	40	42.5	45	45	45	45	45	45	45	47.5	47.5	47.5	50		12.5			
B.T.	50	50	50	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	55	57.5	57.5	57.5		7.5			
Zinovieff																				
B.L.	45	45	45	47.5	47.5	50	57.5	57.5	60	62.5	65	67.5	70	70	77.5		32.5			
T.R.	50	50	52.5	55	55	55	55	55	57.5	60	60	62.5	65	67.5	72.5		22.5			
L.S.	35	35	37.5	40	42.5	45	47.5	47.5	47.5	50	50	52.5	55	57.5	60		25			
N.G.	30	30	32.5	40	40	45	47.5	47.5	50	52.5	52.5	55	57.5	65	67.5		37.5			
One RM				Static Strength (RL)*				Cross Education				Strength Decrement (RL)					Hypertrophy			
DeLorme	Initial	Final		DeLorme	Initial	Final		DeLorme	Initial	Final		DeLorme	Pre*	Post**			DeLorme	Initial	Final	
P.G.	77.5	112.5		P.G.	350	407.5		P.G.	312	315		P.G.	0	-97.5			P.G.	5234.1	5533.3	
D.O.	40	67.5		D.O.	267.5	300		D.O.	240	300		D.O.	-37.5	-70			D.O.	3241.4	3600	
S.W.	52.5	97.5		S.W.	165	247.5		S.W.	160	167.5		S.W.	45	-35			S.W.	3252.5	3304.6	
B.T.	70	87.5		B.T.	212.5	240		B.T.	210	217.5		B.T.	0	-20			B.T.	3763.7	4262.6	
Zinovieff				Zinovieff				Zinovieff				Zinovieff					Zinovieff			
B.L.	65	117.5		B.L.	340	400		B.L.	310	320		B.L.	-35	0			B.L.	3057	3227.5	
T.R.	70	100		T.R.	265	340		T.R.	250	310		T.R.	-75	-70			T.R.	5719	5826.3	
L.S.	50	105		L.S.	167.5	305		L.S.	167.5	330		L.S.	45	-40			L.S.	2404.6	2555.2	
N.G.	80	85		N.G.	227.5	262.5		N.G.	215	225		N.G.	22.5	-10			N.G.	2269.9	2531.5	
				* Right Leg								* Pre-training								
												** Post-training								