Spring 1974

A Comparison of Selected Isokinetic Training Velocities on the Development of Muscular Power in College Women

Julia P. Knight
Old Dominion University

A COMPARISON OF SELECTED ISOKINETIC TRAINING VELOCITIES ON THE DEVELOPMENT OF MUSCULAR POWER IN COLLEGE WOMEN

Julia P. Knight

A thesis presented in partial fulfillment
of the requirements for the Degree of

MASTER OF SCIENCE

DEPARTMENT OF PHYSICAL EDUCATION
OLD DOMINION UNIVERSITY
May, 1974

SUPERVISORY COMMITTEE

Dr. Gerald S. George

Melvin Williams

Charles Jackson

ABSTRACT

The purpose of this study was to compare the effects of three different isokinetic velocities on the development of muscular power. Seventy-five college females were matched into four equal groups according to the average of their pre-test scores on the Vertical Power Jump Test and the Power Staircase Test. Group I served as the control group, while all 3 of the experimental groups performed the same isokinetic exercise at different pre-set rates of speed. Groups II, III and IV worked at the selected rates of .8, 2.3 and 3.9 inches per second respectively. All four groups were pre-tested and post-tested on a Vertical Power Jump Test and a Power Staircase Test to determine the effect of a six-week training program on power in the ankle-knee-hip extensor groups. An analysis of covariance was utilized to determine the effect of the predetermined isokinetic speeds on the performance of leg power on both the two power tests. The Scheffe Multiple Range Test was employed to determine the nature of the specific difference in the study. A Product Moment correlation coefficient was calculated to estimate the relationship which existed between the Vertical Power

Jump Test and the Power Staircase Test. The main findings of this study were:

1. The three different pre-set isokinetic rates of speed significantly improved muscular power in the ankle-knee-hip extensor groups.

2. Although all three selected isokinetic speeds improved leg power, no one speed was significantly more effective as revealed by the results on the two power tests.

3. The Vertical Power Jump Test and the Power Staircase Test correlated for the measurement of muscular power by the ankle-knee-hip extensor muscle groups at the .01 level of significance.

This thesis is dedicated to my Mother and Father, whose patience, pride and perseverance has instilled in me the desire to achieve this goal and to strive for others.

ACKNOWLEDGMENTS

The writer wishes to express her sincere appreciation to Dr. Gerald George for his tolerance, guidance and encouragement throughout the construction of this study.

Appreciation is also extended to Dr. Melvin Williams and Dr. Charles Jackson for their assistance and interest while serving on the thesis committee.

She is especially grateful to Tidewater Community College's maintenance and staff members for their cooperation and to all the subjects for their unselfish efforts and devotion throughout the course of the study. The writer also thanks Ms. Marrie Geerlings and Ms. Beth Barlow for their assistance in the testing and training of the subjects.

VITA

Julia P. Knight was born in Bluefield, West Virginia, on July 3, 1949. She attended public schools in Durham, North Carolina, and was graduated from Charles E. Jordan High School in 1967. She attended the University of East Carolina in Greenville, North Carolina, where she earned the Bachelor of Science degree in Health and Physical Education in May, 1971.

In June, 1971, Ms. Knight began employment with Tidewater Community College, Portsmouth, Virginia, as an assistant instructor in Health, Physical Education and Recreation. In September 1971 Ms. Knight began her Masters degree program at Old Dominion University while employed on a full-time basis at Tidewater Community College.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

THE PROBLEM

There are different training methods currently employed to improve the performance of muscular power. Isotonic and isometric weight training are two basic concepts of resistive exercise that are accepted and employed by coaches and physical educators. An isometric contraction is defined as a muscle contraction in which there is no movement or physical work involved. The muscle can develop near maximum tension, but its length remains constant and the speed of the movement is held at zero. An isotonic contraction is a muscle contraction in which the external resistance is constant to the skeletal lever throughout the entire range of motion. However, the resistance is not constant to the muscle group because of the effects of the lever system through which the resistance must pass. This causes the greatest realized resistance of an isotonic contraction to be at the extremes of the range of the motion. An isotonic contraction is active in nature, with the speed of the body segment varying with the force applied.

In addition to these more conventional weight training methods, isokinetic techniques are adding new dimensions in the field of resistance exercise. An isokinetic contraction is a muscle contraction that is active in nature with the speed of the motion regulated and the resistance in direct ratio to the varying muscle force applied throughout the course of movement. Hence the advantages of selected speeds can be employed specific to the desired effects of the athletic event. If the training speed is set at a rate where a muscle can contract at its maximum work performance, then maximum muscular power can be achieved.[1, 2, 3] This study was primarily predicated upon determining whether any differences existed among various pre-set rates of speed for the assessment of muscular power.

In many athletic events muscular power was considered to be a most important factor for successful

---

[1]Helen J. Hislop and James J. Perrine, "The Isokinetic Concept of Exercise," Physical Therapy, 47:114-17, February, 1967.

[2]Howard G. Thistle and others, "Isokinetic Contraction: A New Concept of Resistive Exercise," Archives of Physical Medicine and Rehabilitation, 48:279-82, June, 1967.

[3]Jim Wilson, "Isokinetics for Maxi-Programs," Athletic Journal, 53:39, 91-93, April, 1973.

performance. The development of leg power has been a special concern in the performance of athletes who participate in activities of a running and jumping nature. The literature revealed several different training methods and testing procedures that were employed and evaluated in an attempt to determine how leg power may best be developed and measured. Leg power tests ranged from the vertical and standing broad jumps to the stair running tests. For a number of years, the results of the vertical jump test have been used as a measure of power and correlated with other leg power tests. The effectiveness of these tests as true measures of power were questioned by some investigators.[4, 5] Research has indicated a need to determine the validity of power tests and the degree of correlation that exists between the various tests. As a secondary problem, this study determined the degree of correlation between two modified power tests.

---

[4]David A. Barlow, "Relationship Between Power and Selected Variables in the Vertical Jump," Selected Topics in Biomechanics, ed. J. M. Cooper (Chicago: The Athletic Institute, 1971), pp. 233-41.

[5]William J. Considine, "A Validity Analysis of Selected Leg Power Test, Utilizing a Force Platform," Selected Topics in Biomechanics, ed. J. M. Cooper (Chicago: The Athletic Institute, 1971), pp. 243-50.

STATEMENT OF THE PROBLEM

The primary purpose of this study was to compare the effectiveness of three different pre-set isokinetic rates of speed on the improvement of collective muscle power in the ankle-knee-hip extensor groups. A sub-problem was to correlate two different power tests, the Vertical Power Jump Test and the Power Staircase Test.

SIGNIFICANCE OF THE STUDY

A limited amount of research has been published on isokinetic training programs and their influence on the development of muscular power. Research also has revealed few weight training investigations involving female subjects. Physiologists and health educators have taken issue with the many myths concerning women participating in weight training activities. More weight training studies are needed involving the female to determine the effects of the exercise methods on her performance.

Leg power was chosen as the selected parameter because it plays such an important role in a majority of sport skills. Further knowledge of isokinetic training and its usages for power gains would benefit the physical educator and the coach endeavoring to improve athletic performance, particularly in females. This type of research may also assist the therapist seeking new methods of improving treatment programs.

In addition, there have been numerous techniques and approaches to the measurement of power itself. Recently the literature indicated opposing points of view over the significance of power tests, especially those which are frequently used in physical education classes. Different opinions are expressed concerning the correlation of various power tests. Because of the diversity of opinions over the available power tests, the determination of the correlation of those tests measuring leg power has been a matter of speculation.

METHODOLOGY

Eighty-four non-athletic female subjects, ranging from 18 to 30 years of age, from physical education classes volunteered to participate in the study. The subjects were matched into four equal groups according to the average of their pre-test scores on the Vertical Power Jump Test and the Power Staircase Test. Nine subjects were dropped from the study because they did not meet for training or complete the post-tests. Group I, the control group, participated in non-related physical education activities that did not involve any weight training exercises. All three of the experimental groups participated in the same non-related physical education activities as well as performed isokinetic exercises using an isokinetic machine, the Kinometric Contractor, at different pre-set rates of speed. Groups II, III and IV worked at the pre-set rates of .8 inches per second, 2.3 inches per second and 3.9 inches per second respectively. All four groups were pre-tested and post-tested on a Vertical Power Jump Test and a Power Staircase Test to determine the effect of a six-week training program on power in the ankle-knee-hip extensors.

TERMINOLOGY

The following definitions of terms were listed for use in the study:

Ankle-knee-hip extensors. The ankle-knee-hip extensors allowed for standing and squatting movements. Those muscle groups involved (1) Triceps Surae; (2) Gluteus Group; (3) Back Extensor Group; (4) Quadriceps Group.[6]

---

[6]Harold B. Falls, Earl L. Wallis and Gene A. Logan, Foundations of Conditioning, (New York: Academic Press, Inc., 1970), pp. 9-10.

Bout. One bout equalled 30 seconds of standing and squatting movements while utilizing the ankle-knee-hip extensors on the Kinometric Contractor.

Isokinetic exercise. In the performance of this accommodating resistance exercise, both concentric and eccentric muscle contractions are employed against a resistance that moves at a pre-set rate of speed regardless of the force applied.[7]

Isometric exercise. This exercise, being a type of static contraction, does not involve concentric or eccentric muscle contractions; rather, a force is applied against an immovable object causing tension to increase but muscle fibers to remain constant.[8]

Isotonic exercise. This type of dynamic contraction is an exercise performed with both concentric and eccentric muscle contractions against a movable resistance. The

---

[7]Helen J. Hislop and James J. Perrine, "The Isokinetic Concept of Exercise," *Physical Therapy*, 47:114-17, February, 1967.

[8]Robert P. Sorani, *Circuit Training* (Dubuque, Iowa: William C. Brown Publishing Company, 1966), pp. 64-66.

amount of force applied and overload present determine the rate of speed.[9]

Kinometric Contractor. The Kinometric Contractor refers to the electrically driven motor that is employed for the performance of the isokinetic exercise training. This device provides a resistance that moves at predetermined rates of speed throughout the entire range of motion regardless of the amount of applied muscular force.[10]

Modified Dip Regulator. This device is a modification of the dip regulator designed and employed by Martin and Stull.[11] It is a wooden and metal device utilized to assure that the subjects initiated their vertical jumps at a 115 degree knee angle and their isokinetic exercises at a 90 degree knee angle.

Power Staircase Test. Margaria's Power Staircase Test was employed with the modification of an electric clock

---

[9]Ibid.

[10]James H. Johnson, "A Comparison of the Effectiveness of Isometric Exercises and Exercise Performed on the Kinometric Contractor in Developing Strength," (unpublished Master's thesis, Louisiana State University, 1967), pp. 1-49.

[11]Thomas P. Martin and G. Alan Stull, "Effects of Various Knee Angle and Foot Spacing Combinations on Performance in the Vertical Jump," Research Quarterly, 40:324-31, May, 1969.

sensitive to a thousandth of a second to time the vertical distance traveled instead of the original clock sensitive to a hundredth of a second. This test measured the maximal muscular power performed with the units expressed in foot-pounds per second. Power was calculated after determining: (1) the subject's weight in pounds, (2) the total vertical height of the staircase units, and (3) the amount of time it took to ascend the vertical distance of the staircase. The staircase consisted of seven units with each unit measuring twice the size of a normal step (1 unit equalled an average of 1.22 feet).[12]

Muscular Power. Muscular power involved the time necessary for a group of muscles to complete a given work-load. Power was defined as the rate at which work was done and may be expressed in a variety of ways, such as foot-pounds per second or horsepower.[13]

Overload Principle. This principle is any exercise or resistance that exceeds in intensity or duration the

---

[12]R. Margaria, P. Aghemo, and E. Rovelli, "Measurement of Muscular Power (Anaerobic) in Man," Journal of Applied Physiology, 21:1661-64, November, 1966.

[13]Philip J. Rasch and Roger K. Burke, Kinesiology and Applied Anatomy (Philadelphia: Lea and Febiger, 1967), p. 143.

demands normally placed upon the body. The important aspect of overload is not the total work output alone, but the total amount of work done in a unit of time.[14]

Vertical Power Jump Test. The Vertical Power Jump developed by Gray, Start and Glencross[15] was used with the modifications of a knee measurement of 115 degrees at the starting position instead of the original starting "crouched" position and the elimination of the body's center of gravity measurement. The Vertical Power Jump was a test for muscular power performance with units expressed in horsepower or foot-pounds of work done per second by the subject's legs. The produced muscular power was equated after determining: (1) the body weight in pounds, (2) the vertical distance from chalked finger marks in a crouched position of 115 degrees angle at the knees to a tiptoe position, (3) the vertical distance from chalked finger marks on tiptoes to the top of the jump position, and (4) the acceleration of gravity (32 ft./sec.^{2}).[16]

---

[14]Robert P. Sorani, Circuit Training (Dubuque, Iowa: William C. Brown Publishing Company, 1966), pp. 64-66.

[15]R. K. Gray, K. B. Start and D. J. Glencross, "A Test of Leg Power," Research Quarterly, 33:44-50, March, 1962.

[16]Herbert A. deVries, "Measurement of Muscle Power," Laboratory Experiments in Physiology of Exercise, (Dubuque, Iowa: William C. Brown Publishing Company, 1971), pp. 15-18.

DELIMITATIONS

This study was delimited in the following manner:

1. Eighty-four non-athletic females between the ages of 18 and 30 were matched according to the pre-tests into four equal groups.

2. One week before pre-testing, all 84 subjects performed five learning trials on each of the two power tests, the Vertical Power Jump Test and the Power Staircase test.

3. During the pre-test and post-test all subjects performed the Vertical Power Jump Test and the Power Staircase Test three times. An average score of the three trials was recorded in horsepower units for each subject. For purposes of initially matching the subjects into four equal groups, an average from each of the two pre-test scores was equated for each subject.

4. The three experimental groups performed 3 bouts of 30 seconds at selected pre-set rates of speed, 3 days per week, for six weeks.

5. The selected rates of speed consisted of .8 inches per second, 2.3 inches per second and 3.9 inches per second for Groups II, III, and IV respectively.

6. Only the ankle-knee-hip muscle extensors were used for training each group in a squat-stand movement pattern.

7. While on the Kinometric Contractor, the subject performed a squat-stand movement that ranged from a 90 degree angle to a 180 degree angle at the knee.

8. A 115 degree angle at the knee was used as the initial squatting position for the Vertical Power Jump Test.

9. Each subject performed her pre- and post-tests at the same hour of the day.

LIMITATIONS

The study was limited in the following manner:

1. Because of the time required to administer the two power tests, it was not possible to test all 84 subjects at the same hour of the day.

2. Although each subject was equally motivated to put forth her maximum effort during the testing and the training period, there was no available device to measure the actual effort exerted.

3. Although an attempt was made to standardize the subjects' daily habits, no control over diet, sleep or daily exercise habits could be monitored fully.

4. While attempts were made to restrict movements to those specific body parts involved in the two power tests and the isokinetic training techniques, extraneous body movement on the part of the subject was a possibility.

5. Although an attempt was made to calibrate all experimental apparatus, inherent errors may have still been present.

6. Not all three experimental groups could train at the same time of the day during the study.

7. Although all the subjects participated in the same physical education activity during the six weeks of training and even though the activity did not place a direct stress on the ankle-knee-hip extensors, these aspects could have affected the study's results.

HYPOTHESES

Two different null hypotheses were used stating: (1) that there were no significant mean differences among the groups for the development of power in the ankle-knee-hip extension muscle groups at the .01 level, and (2) that there was no significant correlation between the Power Staircase Test and the Vertical Power Jump Test for the measurement of muscular power in the ankle-knee-hip extension muscle groups at the .01 level.

Chapter 2

REVIEW OF THE LITERATURE

For purposes of clarity and organization of the study, the review of literature was divided into three major sections: (1) studies related to measurement of power gains, (2) studies related to isokinetic training and power, and (3) a general summary of the literature.

STUDIES RELATED TO MEASUREMENT OF POWER GAINS

As early as 1921, Dudley A. Sargent originated and reported the Sargent Jump Test as a performance test which purported to evaluate the "physical efficiency of human effort." The vertical jump measurement was expressed in terms of an efficiency index, taking into account the subjects height, weight and the vertical distance jumped. This attempt to measure the power factor in human performance was recognized by the relationship of the work done, the time taken and the force exerted.[1] In 1924, L. W. Sargent reported

---

[1]Dudley A. Sargent, "The Physical Test of a Man," American Physical Education Review, 26:188-94, April, 1921.

the Sargent Jump as a "test of neuromuscular efficiency involving strength, speed, coordination, and driving power."[2] Englehardt modified the Sargent Jump by applying the formula:

$$\text{Physical Index} = \frac{\text{Sum of Jumps in 15 Seconds} \times \sqrt{\text{Weight}}}{\text{Height of Stature}}$$

This modification more closely measured driving power while not emphasizing the features of "static bodily measurements or acquired athletic skill."[3] The testing of power was now influenced by the scientific methods introduced into physical education and recognized as a distinction from muscular strength. Power was identified mainly as a force component and a velocity component. The force-velocity relationship in power activities was adopted in many of the so-called strength tests, the tendency being to include a test of force and a test of velocity. The McCurdy Strength Test was an illustration of this principle, in which the Physical

---

[2]L. W. Sargent, "Some Observations on the Sargent Test of Neuro-muscular Efficiency," American Physical Education Review, 29:47-56, February, 1924.

[3]J. L. Englehardt, "A Test of Physical Efficiency," Journal of Educational Psychology, 15:573-78, December, 1924.

Capacity Index was calculated by the total force (sum of leg, back and arm strength) multipled by the velocity (the vertical jump) divided by 100. This test was valid in terms of athletic achievement giving a coefficient of .93.[4] Other strength tests to adopt the principle of power tests as force and velocity components were devised by Cozens,[5] Larson,[6] and Phillips.[7]

C. H. McCloy reported that the Sargent Jump was not a test of strength, but primarily a test of the ability of the body to develop power relative to the weight of the individual. Power was defined as the rate at which a given task could be performed, or force times velocity. Therefore, the jump was a "measure of the way in which force can combine with the highest possible contraction-velocity of the

---

[4]L. A. Larson and R. D. Yocom, Measurement and Evaluation in Physical, Health and Recreation Education (London: Henry Kempton, 1951), pp. 84-5.

[5]F. W. Cozens, "Strength Tests as Measures of General Athletic Ability in College Men," Research Quarterly, 11: 45-52, March, 1940.

[6]L. A. Larson, "A Factor and Validity Analysis of Strength Variables and Tests with a Combination of Chinning, Dipping and Vertical Jump," Research Quarterly, 11:82-96, December, 1940.

[7]B. E. Phillips, "The J. C. R. Test," Research Quarterly, 18:12-29, March, 1947.

muscles so as to project the body upward to a maximum height." McCloy continued to describe the essentials of power and the Sargent Jump, by stating:

> A number of athletic performances are likewise power events. This is true of most track and field events; the sprints, the jumps, and the throws are all events demonstrating maximum muscle contraction over a minimum of time. Since speed and vigor of movement are characteristic of many of the athletic sports such as football, baseball and basketball it would follow that the Sargent jump <u>should</u> be an excellent item to be included in a battery of tests designed to test, among other things, this item of explosive muscular contraction. Obviously this jump is not a test of specific skill or learned game-co-ordinations, neither is it a test of courage, athletic headwork, or great strength.[8]

Barrow and McGee supported McCloy's interpretations concerning the elements of power by stating:

> Power is frequently measured by some type of jump, charge, or throw. The vertical jump and the standing broad jump are most commonly used to measure leg power. A shot put or medicine ball put may be used to indicate power in the arms and shoulders. A charge at a blocking sled may measure body power. Power is required for efficiency in such activities as jumping for height or distance, kicking a soccer ball or football, throwing or putting a ball or weight, striking with a bat or club, charging an opponent, and sprinting with short bursts of speed. In addition to the factors of speed and strength, power is limited by such factors as weight, muscle viscosity, and body structure.[9]

The reason for the popular usage of the Vertical Jump or Sargent Jump as a measure of power is due to the

---

[8] C. H. McCloy, "Recent Studies in the Sargent Jump," <u>Research Quarterly</u>, 3:235-42, May, 1932.

[9] H. M. Barrow and R. McGee, <u>A Practical Approach to Measurement in Physical Education</u> (Philadelphia: Lea and Febiger, 1971), p. 122.

modifications that make it suitable for almost any situation. Some of those modifications are reported by Collins and Howe[10] and by Phillips.[11] Rarick[12] eliminated arm movements while Latchaw[13] improved the scoring techniques. Van Dalen used 106 senior high school boys to clarify and validate various types of vertical jumps under optimum conditions and to statistically determine their weaknesses. Some of the modifications of the Sargent Jump included: the chalk jump, the jump and reach, the wall jump, the belt jump, and the weight jump. The results indicated that out of the six vertical jump forms, the Sargent Jump was a valuable test for predicting the ability to develop power when "standardized, practiced, and correctly administered."[14]

In 1962, Gray, Start and Glencross reviewed the different vertical jumps and concluded that they could not be

---

[10]V. D. Collins and S. C. Howe, "A Preliminary Selection of Tests of Fitness," American Physical Education Review, 29:63-71, December, 1924.

[11]Phillips, loc. cit.

[12]L. Rarick, "An Analysis of the Speed Factor in Simple Athletic Abilities," Research Quarterly, 8:89-103, December, 1937.

[13]M. Latchaw, "Measuring Selected Motor Skills in the Fourth, Fifth and Sixth Grades," Research Quarterly, 25:439-49, December, 1954.

[14]Deobold Van Dalen, "New Studies in the Sargent Jump," Research Quarterly, 11:112-15, May, 1940.

regarded as tests of pure leg power because factors other than leg power were included in the measurements, such as the arm movement used to thrust the trunk upward. Also, the formula based on height jumped and the individual's weight and height did not comply with the mechanical force-time-distance aspects of power. By modifying the Sargent Jump, Gray and his colleagues devised a quantitative measure of power. The total work performed and the time in which the work was done was calculated to determine the vertical leg power of the subject. The final measure of power was expressed in units of horsepower. The Vertical Power Jump had a test-retest correlation of .985 and a coefficient of objectivity of .981.[15] Later, Gray, Start and Glencross modified the Vertical Power Jump because it required time to administer and to mathematically calculate the physical principle of power. The Modified Vertical Power Jump was administered the same as that specified for the Vertical Power Jump, except the measurement related to the center of gravity and the positions of the horizontal gravity line was omitted. When compared to the jump and reach test, the standing broad jump, and the squat jump as a measure of leg power, the Modified Vertical Power Jump had the greatest test-retest reliability score of .977. The Modified Vertical

---

[15]R. K. Gray, K. B. Start and D. J. Glencross, "A Test of Leg Power," Research Quarterly, 33:44-50, March, 1962.

Power Jump also had the highest validity (.989) when correlated with the Vertical Power Jump.[16]

Because power is an important factor in physical activities, researchers have included one or several tests of power in tests of physical fitness, motor and athletic ability, and general motor capacity and educability. McCloy[17] and Larson[18] used the vertical jump as a measure of power in studying the relationship between the jump and the subject's ability to perform general motor skills. Studies using measures of power in tests of physical fitness are reported by Cousins,[19] Blish and Scholz[20] and Anderson and McCloy.[21] The vertical jump also was used as a measure of

---

[16]R. K. Gray, K. B. Start and D. J. Glencross, "A Useful Modification of the Vertical Power Jump," Research Quarterly, 33:230-35, May, 1962.

[17]C. H. McCloy, "Recent Studies in the Sargent Jump," Research Quarterly, 3:235-42, May, 1932.

[18]L. A. Larson, "A Factor and Validity Analysis of Strength Variables and Tests with a Combination of Chinning, Dipping and Vertical Jump," Research Quarterly, 11:82-96, December, 1940.

[19]C. F. Cousins, "A Factor Analysis of Selected Wartime Fitness Tests," Research Quarterly, 26:277-88, October, 1955.

[20]T. E. Blish and A. K. Scholz, "A 10-Year Survey of Physical Fitness Tests at Yale University," Research Quarterly, 28:321-326, December, 1957.

[21]T. Anderson and C. H. McCloy, "The Measurement of Sports Ability in High School Girls," Research Quarterly, 18:2-11, March, 1947.

general athletic performance by Phillips' J. C. R. Test[22] and Bovard and Cozens' Physical Ability Test.[23] In 1972, Huffman and Berger tested 50 students on the vertical jump, the modified vertical jump, Barrow's Motor Ability Test, and the AAHPER Youth Fitness Test to determine whether relative or absolute leg power was a more accurate predictor of physical performance. The results revealed that there was no significant difference between the Modified Vertical Power Test and the Vertical Jump Test as predictors of motor performance in either the Barrow or the AAHPER tests. However, both leg power tests did correlate significantly with the motor test variables. It was concluded that both the Vertical Jump Test and the Modified Vertical Power Jump predicted motor ability and physical fitness with similar accuracy.[24]

For a more accurate measurement of the variable force, velocity, power, time interval and height displacement factors involved in the standing vertical jump Gerrish

---

[22] B. E. Phillips, "The J. C. R. Test," Research Quarterly, 18:12-29, March, 1947.

[23] John Bovard and Frederick Cozens, "The 'Leap-Meter,' An Investigation into the Possibilities of the Sargent Test as a Measure of General Athletic Ability," Physical Education Series, 1:19-123, June, 1928.

[24] Walter B. Huffman and Richard A. Berger, "Comparison of Absolute and Relative Leg Power as Predictors of Physical Performance," Research Quarterly, 43:468-71, December, 1972.

used a force-meter and a sixteen millimeter camera. The force-meter indicated the hydrostatic pressure exerted by the subject while the motion pictures allowed for the plotting of a velocity and force curve which determined a final power curve.[25]

Recently, Barlow demonstrated that the standard vertical jump tests administered in most physical education classes did not actually represent power. The investigation was conducted because of the lack of sound mechanical principles in previous measurements of jumping power. The purpose of the study was to examine the relationship between power and measures of vertical displacement in the Jump and Reach Test and the Modified Vertical Power Jump. Three 16 mm filmed recordings were taken for each of the two jumping tests. Each of the 30 male subjects performed a total of 6 vertical jumps during a 30 minute filming session. This performance was preceded by the recording of body weight, stature, and age. Specific frames for the best performance in each jumping technique were selected for analysis. Optimal performance in each technique was determined by the

---

[25]Paul H. Gerrish, A Dynamic Analysis of the Standing Vertical Jump (New York: Columbia University Publishing Co., 1934), pp. 1-28.

maximum vertical displacement of each subject's center of gravity. Following the collection of data from the films, appropriate calculations were performed to determine center of gravity, displacement, velocity, and power developed. All major calculations were based on knowing the exact film location of the total body center of gravity. Results indicated a negligible relationship between measures of vertical displacement and power obtained in both jumping techniques. Total displacement of the center of gravity from the lowest to peak position was nonrelated to power in the Jump and Reach Test and the Modified Vertical Jump ($r = .04$ and $- .08$, respectively). These results "strongly indicated that total vertical displacement of the center of gravity was not a significant factor in the development of power." Power and total body weight were shown to have a high positive linear relationship in both the power tests. This variable of weight was moderately related to physical height.[26]

Considine's study supported earlier findings after conducting an investigation to ascertain and analyze the validity of selected tests as measures of leg power. The leg power tasks included: (1) the vertical jump and reach

---

[26]David A. Barlow, "Relationship Between Power and Selected Variables in the Vertical Jump," Selected Topics in Biomechanics, ed. J. M. Cooper (Chicago: The Athletic Institute, 1971), pp. 233-41.

test, (2) the chalk board jump test, (3) the standing broad jump test, (4) a 5 yard sprint test, (5) a 10 yard sprint test, and (6) a 5 yard sprint performance with a 5 yard running start. The performance of the six power leg tasks was correlated with a criterion performance task that was similar to the original Sargent Jump. This task required the subjects to assume the initial starting position on a force platform. This platform enabled the investigator to determine the components of power. It measured: (a) weight of the man in pounds, (b) the time, in 100th of a second, over which the force was applied, and (c) the total time, in 100th of a second, when the body was in the air during a vertical jump performance. There were 105 male students tested on multiple trials of the selected tests and the criterion performance test. Results indicated that all the power tests had limited relationships to the criterion test. The obtained validity coefficients indicated that the six power tests could not be justified as valid measures of leg power. The Vertical Jump and Reach Test was found to possess the greatest relationship to the criterion measure; however, the test "did not seem to be a valid method by which to assess true leg power." It was concluded also that regression equations, based upon the selected tests, height, and weight, and designed to predict power, are of little practical value because of the moderate degree of interrelations between the selected test variables. Considine recommended:

> The practitioner in the field of physical education should not attempt to assess the power output of human performance. Rather, he should concentrate his concern on the product of that power output since the achievement of that performance is the essence of man's endeavor.[27]

Glencross also questioned the validity of the common tests of muscular power. He introduced a power lever that measured muscle power "unidimensionally." It was based upon the mechanical principle of power, the rate of doing work. This was achieved by measuring the force, distance, and time developed by the body when using the power lever. The validity of the device depended upon the conditions involved in the application of the mechanical principles to human movement.[28] Glencross applied these principles of the power lever to determine the validity of the jump-reach test and the standing broad jump as tests of muscle power. The results

---

[27]William J. Considine, "A Validity Analysis of Selected Leg Power Tests, Utilizing a Force Platform," Selected Topics in Biomechanics, ed. J. M. Cooper (Chicago: The Athletic Institute, 1971), pp. 243-250.

[28]Dennis J. Glencross, "The Power Lever: An Instrument for Measuring Muscle Power," Research Quarterly, 37:202-10, May, 1966.

revealed that the two tests had "limited application as valid measures of muscle power as measured by the power lever as the criterion."[29] Start calculated leg power in mechanical and mathematical concepts with the use of a Weighing Machine. The machine gave the static weight of each subject standing on the machine and the dynamic weight of each subject performing the Sargent Jump off the machine.[30] Several other investigators recommended the use of motion or stroboscopic photography for a more detailed analysis of the velocity, acceleration, and power exerted during the power test.[31, 32, 33, 34, 35]

---

[29] Dennis J. Glencross, "The Nature of Vertical Jump Test and the Standing Broad Jump," Research Quarterly, 37:353-59, October, 1966.

[30] K. B. Start, "Measuring Power by Physical Rather Than Physical Educational Methods," New Zealand Journal of Physical Education, 23:35-37, April, 1961.

[31] Barry L. Johnson, "Establishment of a Vertical Arm Pull Test (Work)," Research Quarterly, 40:237-39, March, 1969.

[32] C. A. Koepke and L. S. Whitson, "Power and Velocity Developed in Manual Work," Mechanical Engineering, 62:383-89, 1940.

[33] Barlow, loc. cit.

[34] Glencross, loc. cit.

[35] Dennis J. Glencross, "The Mechanical Analysis of the Standing Broad Jump and Vertical Jump," New Zealand Journal of Physical Education, 3:29-37, July, 1964.

Despite the popular use of the vertical jump as a testing device for measuring muscular power, there was little literature devoted to the many factors which affect the subject's maximum exertion of the jump. In two separate studies, Pacheco reported highly significant effects on performance due to warm-up exercises.[36, 37] Willson concluded from his study on foot spacing in the vertical jump that there should be little or no anterior-posterior spacing, and that the lateral spacing could vary up to ten inches without retarding the performance of the jump.[38] Martin and Stull tested 30 young adult males on the Vertical Jump and Reach Test at knee angles of 65, 90, and 115 degrees while using lateral and anterior-posterior foot spacings of 0, 5, 10, and 15 inches. At the .01 level of confidence, it was found that a knee angle of 115 degrees resulted in the best performance in the vertical jump. Also, the results revealed

---

[36]Betty A. Pacheco, "Improvement in Jumping Performance Due to Preliminary Exercise," Research Quarterly, 28:55-63, March, 1957.

[37]Betty A. Pacheco, "Effectiveness of Warm-up Exercise in Junior High School Girls," Research Quarterly, 30:202-13, May, 1959.

[38]Kent R. Willson, "The Relative Effects of Various Foot Spacing on Performances in the Vertical Jump," (unpublished Master's problem, Pennsylvania State University, 1965), pp. 1-40.

that the lateral foot spacing of 5 to 10 inches and the anterior-posterior foot spacing between 5 and 10 inches, but closer to 5 inches, are the best positions for vertical jumping performance.[39]

The literature revealed a variety of tests other than the jump tests which measured muscular leg power. Margaria, Aghemo, and Rovelli devised a simple test, consisting of a set of ordinary stairs, to assist in the measurement of muscular power. Using an electronic clock and photoelectric cells, the test measured the maximal speed with which a subject could run up a set of stairs, taking two steps at a time. The muscular power for each subject was calculated by dividing the mean time from the running trials into the subject's weight times the total step height. The results were expressed in horsepower units. The Margaria Power Staircase Test disclosed several outstanding advantages in that the time needed to perform the test was short, the test did not exhaust the subjects, the exercise did not require any particular training, and it accounted for the

---

[39]Thomas P. Martin and G. Alan Stull, "Effects of Various Knee Angle and Foot Spacing Combinations on Performance in the Vertical Jump," Research Quarterly, 40: 324-31, May, 1969.

subject's body weight in the calculation of power.[40] Kalamen discovered that the maximum power in man was reached by running stairs three at a time with a 6-meter start. He compared this modified Power Staircase Test to the Sargent Jump and found no significant correlation between them. When determining if the results of either of the two tests could predict success in sprinting, Kalamen found that adequate predictions could be made by the maximum power test scores.[41]

The literature indicated the ever increasing usage of different power tests. The application and measurement of these tests have claimed to predict a variety of characteristics, such as jumping ability, specific power movements, coordination, and general athletic and motor ability. The validity of some power tests has been questioned because of the criteria to which they were applied and the overgeneralization of implied inference.[42] In order to improve

---

[40]R. Margaria, P. Aghemo, and E. Rovelli, "Measurement of Muscular Power (Anaerobic) in Man," Journal of Applied Physiology, 21:1662-4, 1966.

[41]James L. Kalamen, "Measurement of Maximum Power in Man," Completed Research in Health, Physical Education and Recreation, 12:166, 1970.

[42]David A. Barlow, "Relationship Between Power and Selected Variables in the Vertical Jump," Selected Topics in Biomechanics, ed. J. M. Cooper (Chicago: The Athletic Institute, 1971), pp. 233-41.

the measurement of the athlete's performance, further investigation is needed to determine the validity and the correlation of the existing power tests and the proper procedures required to measure muscle power.

STUDIES RELATED TO ISOKINETIC TRAINING AND POWER

Contrary to the more conventional overload training program, isokinetic training methodology has been only briefly explored in recent years for a variety of purposes ranging from improvement in athletic performance to possible usages in physical therapy and rehabilitation. Hislop and Perrine presented an article comparing the nature of isokinetic methodology to that of conventional isometric and isotonic methodologies. The basic differences among the exercise methods consisted in the control of distance in isometrics, the control of resistance in isotonics, and the control of rate in isokinetics. Mathematically, work is equal to force times the distance the resisted object is moved. Isometic overload can be realized only at a fixed point of application. While isotonic exercise allowed for overload throughout a range of motion, the external resistance realized by the skeletal lever system was constant. This meant that the internal muscular resistance could realize an overload factor no greater than the weakest point in the lever's range of motion. However, isokinetic exercise methodology allowed for movement throughout the entire range of motion at a fixed rate of speed regardless of the applied force.[43] In order to load a muscle by the isokinetic principle, a special mechanical device was required. An isokinetic exerciser was defined as:

> An unique speed-controlling mechanism which operates as a dynamic exercise motion. It has suitable input attachments for positioning and holding at fixed, preset speeds and various functional exercise patterns.

Under these conditions, the subject is afforded the opportunity to exert maximally throughout the desired anatomical range of motion. After determining and setting an appropriate exercise speed on the isokinetic exerciser, it is possible for all muscle contractions to develop either maximum (1) tension, (2) work per repetition, or (3) power output or submaximal power output per repetition for the highest time duration.[44] When discussing controlled rates

---

[43]Helen J. Hislop and James J. Perrine, "The Isokinetic Concept of Exercise," Physical Therapy, 47:114-17, February, 1967.

[44]James J. Perrine, "Isokinetic Exercise and the Mechanical Energy Potentials of Muscle," Journal of Health, Physical Education, and Recreation, 39:40-4, May, 1968.

of speed and power output, Hislop and Perrine stated the following:

> In addition to the benefits of holding speed constant in exercise, the isokinetic concept provides the opportunity to manipulate the rate of speed selected so as to establish specific exercise conditions with regard to muscle power output. Once an isokinetic device is set at a specific operating speed, it permits and demands muscular contractions at that speed. If the speed is set at the highest rate at which a muscle can contract and still demonstrate its maximum work performance, then the maximum muscle power output will be achieved. Progressively higher rates of speed set over the course of an exercise program will place increasingly greater demands specifically on the contractile speed of the muscle. Alternately, the speed can be maintained at a calculated (functional) rate until work capacity reaches some optimum level at that rate of contraction. In either case, power output is improved.[45]

Councilman made a comparison of isometric, isotonic, and isokinetic training and specifically applied his findings to the Indiana University swimming team. He stated that the athlete should exercise the same muscle groups throughout those movement ranges that are identical to the desired sport's activity. It was found that isokinetic training possessed the characteristics that most closely resembled the desired activity. He felt that those exercises which provided for a constant, controlled speed of the resistance element would prevent contractual acceleration of

---

[45]Hislop and Perrine, loc. cit.

the muscle and thereby allow for maximum realization of muscular force application throughout its entire range of motion.[46, 47]

Hutinger selected 73 male swimming students to determine the effects of isokinetic, isotonic and isometric developed strength on speed in swimming the crawl stroke. The isokinetic method of strength development was assumed to be superior to that of isometric or isotonic exercise methods. There was a trend toward a greater increase in strength development by isokinetic exercise, as measured by the Mini-Gym. It was not, however, a statistically significant increase when compared to the increases demonstrated in swimming speed or in strength development by the other groups.[48]

Thistle and others employed fifty-one subjects to compare the effectiveness of isometric, isotonic and isokinetic training in terms of gains in muscular strength. A

---

[46]James Councilman, "Isokinetic Exercise: A New Concept in Strength Building," Swimming World, 10:15, November, 1969.

[47]James Councilman, "Isokinetic Exercise," The Athletic Journal, 53:58, February, 1972.

[48]Paul W. Hutinger, "Comparison of Isokinetic, Isotonic and Isometric Developed Strength to Speed in Swimming the Crawl Stroke," (unpublished Doctor's dissertation, Indiana University, 1970), pp. 1-90.

Cybex Exerciser was utilized by the isokinetic training group. This device consisted of a lever arm that could be easily attached to the body to allow for a constant rate of speed regardless of the varying degrees of muscular force being applied throughout the range of motion. The findings showed an improvement of 35.4 per cent in total work ability for the isokinetic group, 27.5 per cent for the weight lifting group, and 9.2 per cent for the isometric group. The results of the peak forces measurement gave a 44.2, 28.6, and 12.1 per cent improvement to isokinetics, weight lifting, and isometric training respectively. Not only did the isokinetic training group score significantly higher in terms of strength and maximal force output, but also the subjects commented that there was little muscular and joint pain and that the presence of the visual force-readout gauge confirmed their own work load and motivated their efforts.[49] Other investigators have realized the benefits of accommodating resistive exercises on the Cybex machine. The machine was found to be superior to other techniques in rebuilding impaired leg muscles. The machine also functioned

---

[49]Howard G. Thistle and others, "Isokinetic Contraction: A New Concept of Resistive Exercise," Archives of Physical Medicine and Rehabilitation, 48:279-82, June, 1967.

as a dynamometer in measuring and recording dynamic torque, work performed, and the power rate output of the muscle.[50, 51]

Curtis investigated the running speed and leg power changes of 45 football players while utilizing an Exer-Genie in two specific types of isokinetic programs and a controlled group. There was no significant difference between the two isokinetic programs. However, those players who did participate in either of the two Exer-Genie weight training programs produced significant improvements in speed and power over the non-weight training players.[52]

Tressel used 3 training programs to determine their effectiveness upon dynamic strength, static strength, and speed, as measured by the 35 yard dash. The 3 training programs included weight training, the Exer-Genie, and the Correct-O-Sizer. All 3 treatment groups exhibited significant gains over the control group in dynamic strength, static strength, and speed. The analysis of covariance did

---

[50] Paul M. Elwood, "Stubborn Machine Helps Retain Muscle," Medical World News, September 23, 1966, p. 38.

[51] Frank W. Dick, "Isokinetic Exercise," British Journal of Sports Medicine, 4:27-34, December, 1968.

[52] Richard L. Curtis, "A Comparison of the Running Speed and Leg Power Developed During a Football Season by Two Types of Specific Exer-Genie Programs," (unpublished Master's thesis, California State College at Long Beach, 1969), pp. 1-51.

not indicate any significant differences between treatment groups in strength. It was concluded that all three weight training programs were equally effective in improving running performance in the 35 yard dash.[53]

Sterling and Nicolson compared the relative effectiveness of weight training and an Exer-Genie exerciser as methods of developing muscular strength in isolated muscle groups of thirty junior high school boys. Both groups worked out during the same class period on Monday, Wednesday, and Friday of each week for six weeks. Each subject in the weight training group completed four sets of seven repetitions per set for each period, while each Exer-Genie subject completed two sets of two repetitions per set each time the class met. It was concluded that for the development of strength of the forearm flexor and extensor muscle groups of junior high school boys that the Exer-Genie was equal to or better than weight-training exercises when conducted in the manner investigated.[54]

---

[53]Lea J. Tressel, "The Effects of Selected Resistance Exercise Programs Upon Muscular Strength and Speed," (unpublished Doctor's dissertation, Indiana University, 1968), pp. 1-181.

[54]Leroy F. Sterling and Jerry Nicolson, "A Comparison of Weight Training and Exer-Genie Methods of Strength Development," A paper presented at the Southern District AAHPER, New Orleans, Louisiana, March 1, 1968.

Parsons used elementary school boys in two experimental groups and a control group to determine physical fitness and muscular strength gains. Experimental group A trained using the Exer-Genie, while experimental group B trained using circuit training exercises. The results showed that the Exer-Genie device was a significant innovative apparatus for building fitness. Although the circuit training group showed the greatest gains on the physical fitness index, it did not significantly improve over the Exer-Genie group. It was noted that the Exer-Genie device required less equipment and was used with ease and safety by each student. The Exer-Genie group showed greater improvements over the circuit training group in building strength for specific muscle groups.[55] This study showed the importance of the prescribed Exer-Genie exercises as a valuable method for physical conditioning and improvements of specific muscular strength. Morant compared an Exer-Genie, isometric and isotonic training program for agility, flexibility, muscular endurance, power and speed gains. Following a 12 week training period, the results indicated that

---

[55]Robert E. Parsons, "A Comparison of the Exer-Genie as a Physical Conditioning Device to Traditional Methods of Exercise," (unpublished Master's thesis, Central Washington State College, 1969), p. 97.

there was a significant difference between the isokinetic and isometric groups in the area of agility.[56]

In 1972, Rosentswieg and Hinson compared isometric, isotonic and isokinetic exercises for the development of muscular strength in 13 women. Integrated electromyographic data was recorded as a film simultaneously recorded each maximum contraction of the biceps brachii. This made it "possible to assess muscular activity over any time period of the contraction or at any given angle of elbow flexion." The isokinetic contractions were executed on a Super Mini-Gym at the controlled velocity of 8.1 feet per minute. The isokinetic work appeared to be the preferred type of exercise for strength development of the biceps brachii.[57] In a similar study, Hinson and Rosentswieg stated that:

> On the basis of muscle action potential produced, the isokinetic method of contraction should be favored over the isotonic method since the isokinetic method provides for the full range of motion and produces greater muscle action potential than the isotonic method for a greater number of subjects. No single contraction type was found which produced the greatest

---

[56] Charles Morant, "A Comparison of Exer-Genie, Isometric and Isotonic Training Programs on Selected Components of Motor Ability," Completed Research in Health, Physical Education and Recreation, 13:99, 1971.

[57] Joel Rosentswieg and Marilyn M. Hinson, "Comparison of Isometric, Isotonic and Isokinetic Exercises by Electromyography," Archives of Physical Medicine and Rehabilitation, 53:249-52, June, 1972.

> muscle action potential for all subjects. Strength gain due to a given exercise program would seem, therefore, to vary with the individual and the motor unit involvement elicited by the type of contraction employed.[58]

Gedney tested 64 male college students for static and isotonic elbow flexion strength, muscular endurance, and aerobic capacity before and after a six-week training period. The subjects were divided into 4 groups with Group I training on both the Kinometric Contractor and the bicycle erogometer; Group II riding the bicycle erogometer; Group III exercising on the Kinometric Contractor, and Group IV acting as a control group. The findings concluded that those who trained on the Kinometric Contractor showed significant static and isotonic strength gains compared to the control group. Muscular endurance gains were significant at the .05 level of probability for those who received cardiovascular training.[59] Johnson also tested for dynamic strength gains following a nine-week period of training isometrically and on the Kinometric Contractor. The Kinometric Contractor permitted a subject to achieve a maximum

---

[58]Marilyn Hinson and Joel Rosentswieg, "Comparative Electromyographic Values of Isometric, Isotonic, and Isokinetic Contraction," Research Quarterly, 44:72-78, March, 1973.

[59]Roger H. Gedney, "Effects of Generalized Cardiovascular Training on the Development of Localized Muscular Strength and Endurance," (unpublished Doctor's dissertation, Louisiana State University, 1973), pp. 1-92.

contraction throughout the entire range of movement. Although there were no significant differences between the isokinetic and isometric training groups, they both improved significantly over the control group.[60] This new weight training concept was employed with a variety of tests, training procedures, paramenters, and testing devices. The research revealed that isokinetic exercises were significant training treatments for the improvement of athletic performances in terms of strength and endurance.

Some isokinetic studies have dealt directly with the improvements of muscular power. In a related study, Testone investigated the use of isokinetic training to increase the subject's height of the vertical jump and his strength after a six-week training period. Forty male subjects were divided into an isokinetic training group, executing 15 leg extensions on the Super-Mini-Gym four times weekly, and a control group. At the level of .05 significance, the training groups showed significant gains in strength and in vertical jumping ability. The control group showed no significant gains in the vertical jump but did in strength ability. However, these gains were not as great as the

---

[60] James J. Johnson, "A Comparison of the Effectiveness of Isometic Exercise and Exercise Performed on the Kinometric Contractor in Developing Strength," (unpublished Master's thesis, Louisiana State University, 1967), pp. 1-49.

Other investigators suggested that, for increasing muscular force, work is not as important as the rate at which it is done.[63] In a paper by Muffroid and others, an isokinetic device was tested for its reliability and validity to measure torque, work, range of motion and power. Following a variety of tests for each parameter, isokinetic exercises were recommended as an effective treatment for increasing torque throughout the range of motion. It also was more effective in increasing the work of a muscle than isotonic or isometric treatments. At slow speeds of contraction for the quadriceps and hamstring muscles, the torque curves agreed with isometric forces at various joint positions. At increasing rates of speed, the torque decreased.[64] Further research is being performed to determine the effects of fast and slow isokinetic training velocities on the development of muscular strength in the squat position.[65]

---

[63]F. A. Hellebrandt and S. J. Houtz, "Methods of Muscle Training: Influence of Pacing," The Physical Therapy Review, 38:319-326, May, 1958.

[64]Mary Muffroid and others, "A Study of Isokinetic Exercise," Physical Therapy, 49:735-47, July, 1969.

[65]Based on personal correspondence between Dr. Roger H. Gedney, Professor at Western Illinois University, and the writer, July, 1973.

The literature revealed isokinetic methodology to possess some of the more advantageous characteristics of both the isotonic and the isometric methodologies. The most unique property of the isokinetic contraction was the positive control of the speed throughout the range of motion. When utilizing isokinetic training procedures a significant development of muscular power and other performance abilities were discovered. One way to quantify a muscle's capacity was in terms of the maximum amount of force it developed at different speeds of joint movement. Basically, this concept represents the work rate or power that a muscle can develop at specific rates of speed. Additional research is needed to understand more fully the merits of the isokinetic concept, particularly in terms of its application for the development of muscular power.

SUMMARY

Because muscular power involves the time necessary for a group of muscles to complete a given work-load, it has been recognized as an important factor which contributes to successful athletic performance. The combination of strength and speed of action in muscle groups produced the power element essential to successful accomplishment of athletic skills. Many forms of sport skill, such as jumping, throwing and running have been regarded as measures of muscular power. The assessment usually took the form of the distance jumped or run in a given time. Jumping skills have been utilized as tests of muscle power with the most commonly employed form being a vertical jump. The literature revealed many modifications of the original Sargent Jump, with the reliabilities of the tests inconsistent. The diverse application of the reported tests of muscle power illustrated the lack of agreement of investigators, the inadequacy of the definitions and the misconception as to the nature of muscle power. For these reasons, more research was needed involving muscle power and the correlation between the existing power tests, especially those so frequently used in the physical education classroom.

Weight training methods have made tremendous benefits with the use of the isokinetic resistance exercise. Isokinetic machines allowed for maximum realized resistance throughout the full range of motion. In this type of resistance exercise, the muscle was capable of developing maximum force at any given point in the range of movement. The muscle contractions were employed against an external resistance that moved at a pre-set speed regardless of the force applied. Isokinetic weight training has shown to be successful in eliminating sore muscles, joint pain, efficient use of time and space and changing of loose weights. Studies have indicated that isokinetic exercises were at least as good as isotonic and isometric exercises for the realization of strength, speed, endurance, and power. Few studies have dealt with the effective use of the different isokinetic speeds on the performance of muscular power, especially in females.

Chapter 3

METHODOLOGY

INTRODUCTION

The literature helped to determine the scope of the study and assisted in the planning of the experiment. The methodology set forth in this chapter assesses the effects of the study's weight training treatments. The subjects, apparatus, training methods, tests and treatment of the data are also described for the presentation of the study.

SAMPLE DESCRIPTION

Eighty-four non-athletic female students enrolled in the physical education activity classes at Tidewater Community College, Portsmouth, Virginia, volunteered as subjects for the study. The average of the combined two power pre-test scores was used to match each subject into four equal groups. Table 1 shows the means, ranges and standard deviations for the age of each group.

Table 1

Means, Ranges and Standard Deviations of Each Group's Age

Group	Number of subjects	Mean[a]	Range	Standard deviation
I	21	19.47	18-34	3.430
II	21	19.52	18-28	2.231
III	21	19.19	17-26	1.848
IV	21	19.71	17-33	3.364

[a]Age expressed in years.

Table 2 shows the means, ranges and standard deviations for the weight of each group.

Table 2

Means, Ranges and Standard Deviations of Each Group's Weight

Group	Number of subjects	Mean[a]	Range	Standard deviation
I	21	119.79	92-139	13.960
II	21	128.42	100-205	29.827
III	21	132.75	107-195	22.430
IV	21	129.41	93-182	20.633

[a]Weight expressed in pounds.

Nine subjects were dropped from the study because they did not meet for training or did not complete the post-tests. Nineteen subjects remained in Groups I, II and IV, while Group III had 18 subjects. Tables 3 and 4 show the means, ranges and standard deviations for the age and weight respectively of the subjects remaining in each group.

Table 3

Means, Ranges and Standard Deviations of Each Adjusted Group's Age

Group	Number of subjects	Mean[a]	Range	Standard deviation
I	19	19.42	18-34	3.610
II	19	19.47	18-28	2.317
III	18	19.11	17-26	1.997
IV	19	19.84	17-33	3.516

[a]Age expressed in years.

Table 4

Means, Ranges and Standard Deviations of Each Adjusted Group's Weight

Group	Number of subjects	Mean[a]	Range	Standard deviation
I	19	121.42	92-138	13.605
II	19	128.40	100-205	30.276
III	18	132.80	107-195	23.820
IV	19	129.46	92-182	21.182

[a]Weight expressed in pounds.

PARAMETER MEASURED

The study involved three experimental groups and a control group for possible gains expressed in horsepower unites of the subject's ankle-knee-hip extensor muscle groups. While utilizing the same isokinetic exercise, the experimental groups II, III and IV, trained at the pre-set rates of speed of .8, 2.8 and 3.9 inches per second respectively. This was to determine the advantages, if any, of selected speeds for the assessment of the subject's leg power. The study also statistically correlated two different power tests, a Power Staircase Test and a Vertical Power Jump Test to determine if the two tests related to one another for the measurement of power.

POWER STAIRCASE TEST

In a pilot study involving 18 non-athletic male subjects the Power Staircase Test had a test-retest reliability of .974.[1] Refer to Appendix A for the data. In the present study all four groups were pre-tested and post-tested for maximum power by the Power Staircase Test. Just prior to

---

[1] Julia P. Knight, Pilot Study, Tidewater Community College, Portsmouth, Virginia, July, 1973.

the first training period, each subject, wearing a minimum of gymnasium clothing minus shoes and socks, was weighed on a standard scale. Body weight was recorded to the nearest half pound. Following the recording of the supervised weighing, each of the subjects was tested for maximum leg power on the Power Staircase Test. A solidly constructed staircase was used that consisted of 14 steps or 7 units, each unit with an average vertical height of 1.22 feet. An electric clock sensitive to 0.001 second was employed to time the subjects as they individually ascended the stairs, taking 1 unit at a time.

Each subject took a square stance position behind a strip of tape positioned six feet in front of the first step. This allowed the subject to initiate the climb at approximately her greatest forward velocity. On the second and sixth unit the subject contacted a rubber pad which was attached to the electric clock. Contact with each rubber pad served to respectively start and stop the electric clock. When ready, the subject started the run, putting forth maximum effort throughout the entire climb of the staircase. Each subject performed the Power Staircase Test three times, with an approximate 30 second rest period intervening each trial to minimize any fatiguing effects. The clock recorded the subject's speed from the second to the sixth unit which consisted of a total vertical rise of 4.88 feet. The muscular power for each subject was calculated by dividing the mean for the three runs into the subject's weight times the total step height. The results were expressed in horsepower units. Refer to Appendix D and E for procedures and instructions on the Power Staircase Test.

VERTICAL POWER JUMP TEST

In a pilot study involving 19 non-athletic male subjects the Vertical Power Jump Test had a test-retest reliability of .838.[2] Refer to Appendix B for the data. In the present study all four groups were pre-tested and post-tested using a Vertical Power Jump Test. A jump board measuring 96 x 48 inches and mounted four inches from the wall and two feet from the floor was marked off horizontally at every half inch, enabling the investigator to determine the height of each jump to the nearest half inch. A goniometer was utilized initially to fix the knee angle at 115 degrees. To assure that the subject initiated her jumps from the desired knee angle, a modification of Martin and Stull's dip regulator was employed.[3] This device consisted

---

[2]Julia P. Knight, Pilot Study, Tidewater Community College, Portsmouth, Virginia, July, 1973.

[3]Thomas P. Martin and G. Allan Stull, "Effects of Various Knee Angle and Foot Spacing Combinations on Performance in the Vertical Jump," Research Quarterly, 40:324-331, May, 1969.

of a three foot wooden rod which was attached to a wooden base. To allow for a permanent knee angle recording, the rod was marked every quarter of an inch. A solid metal dip bar was attached to the rod so that it could be easily adjusted to any height. Refer to Figure 1. In a pilot study of 19 non-athletic male subjects the tested reliability of the Modified Dip Regulator was .885.[4] Refer to Appendix C for the data.

When the subject took an initial squatting position of 115 degrees for the Vertical Power Jump Test and 90 degrees for the isokinetic exercise, the dip bar was placed directly beneath the subject's buttocks. A recording was made at this position to the nearest quarter of an inch. Refer to Figures 2 and 3. The dip regulator (1) assured that the subject initiated the jump and exercise pattern at the desired knee angle, (2) eliminated extra stress on the subject's knees caused by maintaining the squat position for numerous knee angle measurements, and (3) lessened the number of knee angle measurements made by the goniometer.

Prior to the Vertical Power Jump Test, each subject's weight was recorded to the nearest half pound. Following a one minute warm up of relatively vigorous running in place

---

[4]Julia P. Knight, Pilot Study, Tidewater Community College, Portsmouth, Virginia, July, 1973.

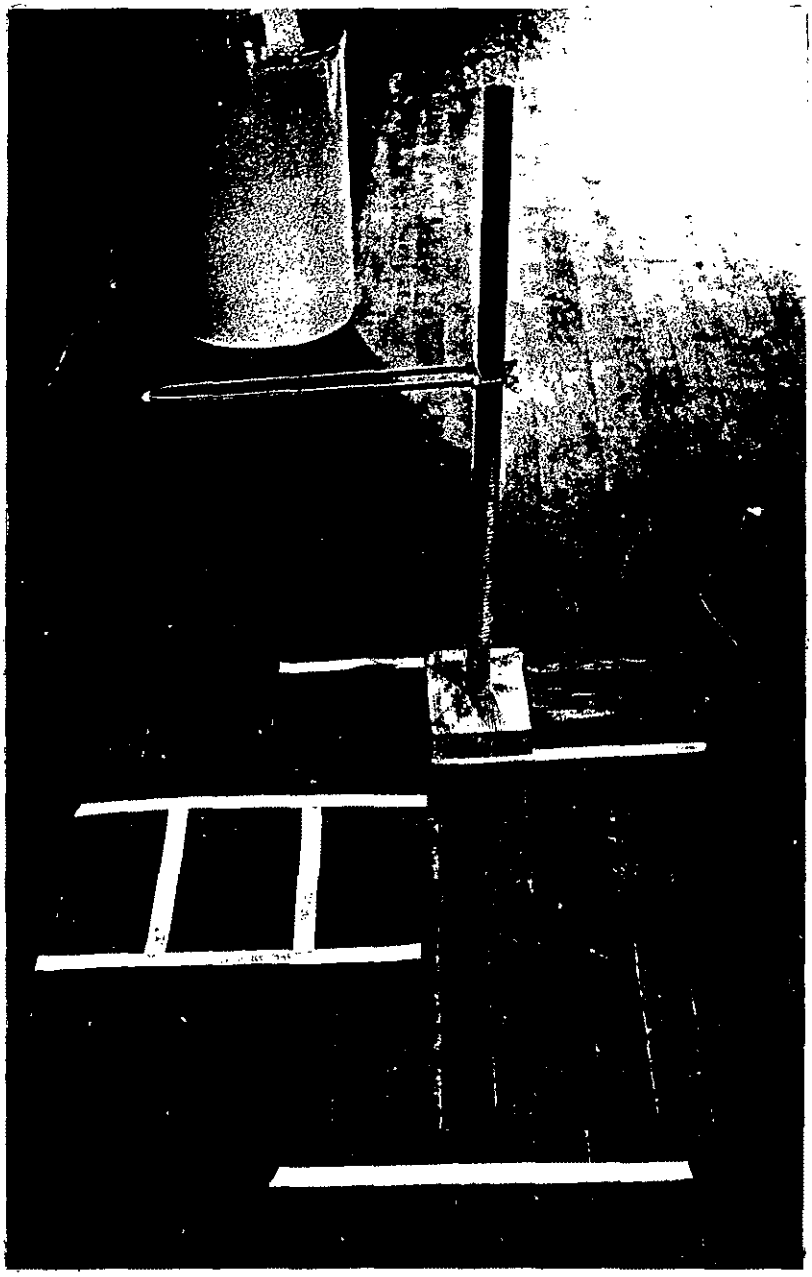

Figure 1

The Dip Regulator and the Lateral Foot Spacing
for the Vertical Power Jump Test

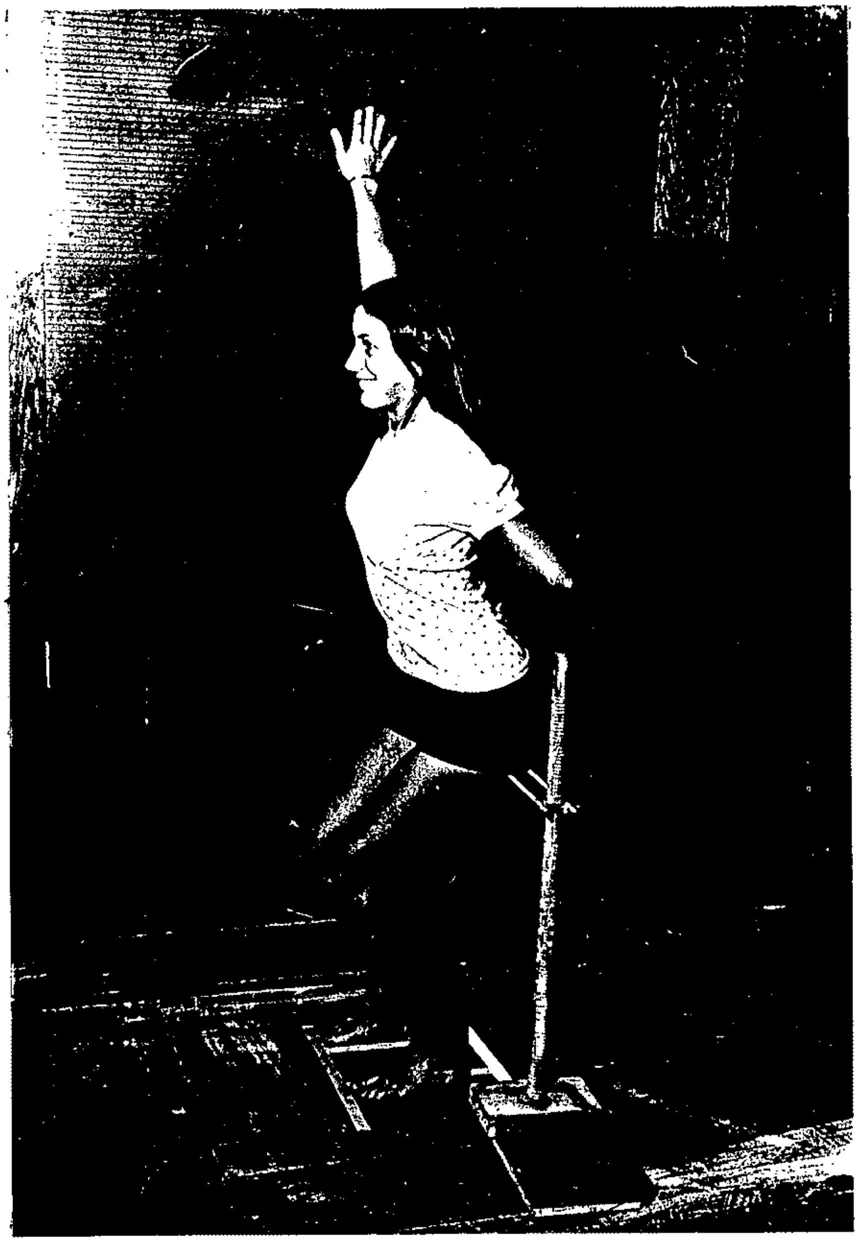

Figure 2

Initial Squatting Position of 115 Degrees for the Vertical Power Jump Test

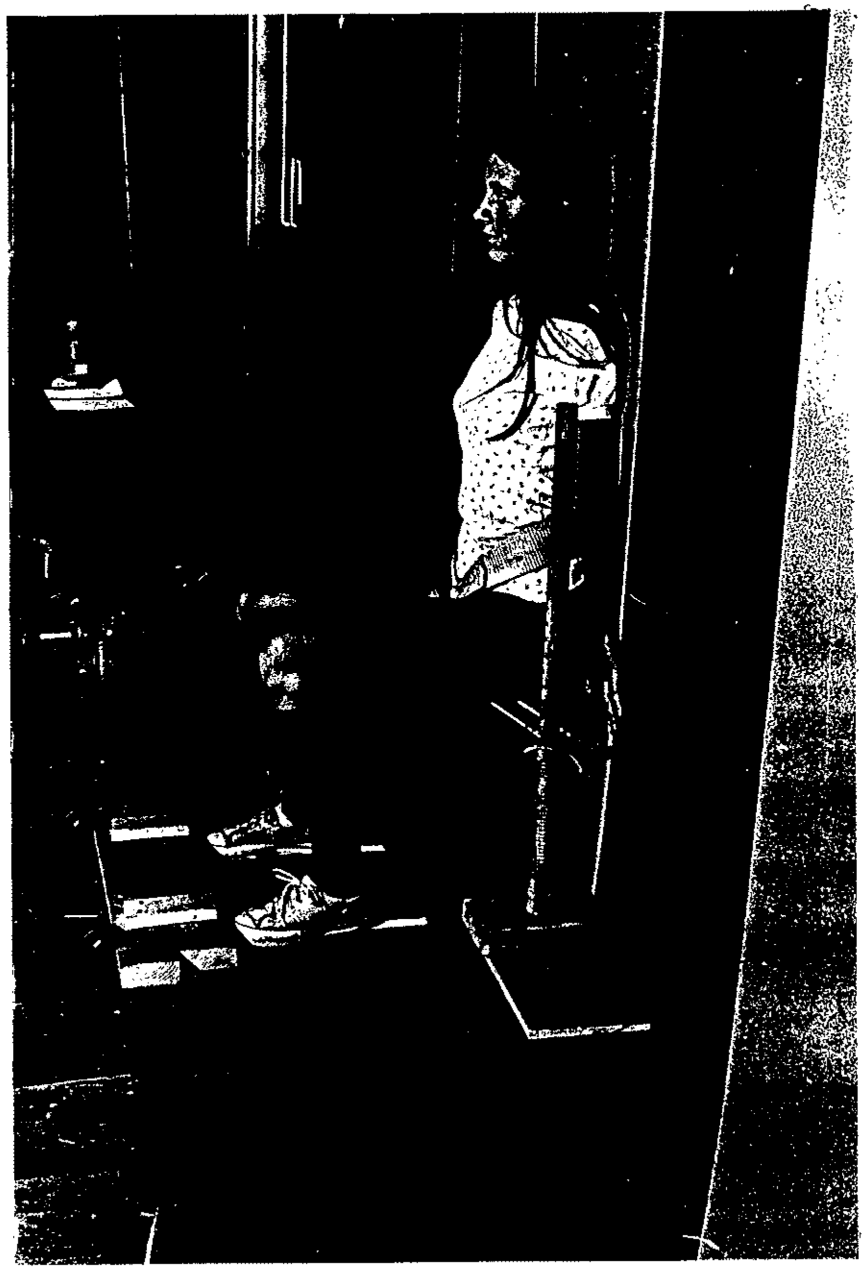

Figure 3

Initial Squatting Position of 90 Degrees
for the Isokinetic Exercise

to a beat of a metronome, the subject then chalked her fingertips with magnesium carbonate chalk and took a standing side position as close to the jump board as practicable. The subject was then instructed to take a lateral foot spacing of 7 inches, which was marked clearly with tape. One hand was secured behind the back while the preferred arm was raised vertically and held steadily against the side of the head. While keeping the head and back erect, the subject dipped until the appropriate knee angle of 115 degrees was attained as measured by the goniometer. She was instructed to maintain that position while the dip bar was placed under her buttocks and the first chalk mark was made by her extended fingertips. This mark was labeled position 1. The subject then was instructed to stand on her tiptoes in a sideways position to the jump board with the back, head, feet, and arms in the same initial position and attempt to reach as high as possible. A second chalk mark was made at that point and labeled position 2. Keeping the same body position, the subject dipped until her buttocks just touched the dip regulator. The test administrator said, "Whenever you are ready, jump!" The subject jumped upward putting forward her maximum effort and marking her highest point of the jump with her chalked fingertips. This mark was labeled position 3. Each subject performed three trials of the

Vertical Power Jump Test, with an approximate 30 second rest period between each trial to minimize any fatiguing effects. The vertical difference in height was calculated from the average of the three chalk marks in position 1 to that of position 2 and from the average chalk mark between position 2 and position 3. Power was determined by using the following formula:

$$\text{Power (in hp)} = \frac{w\ (h_1 + h_2)}{550\ h_1} \times \sqrt{\frac{gh_2}{2}}$$

where w = body weight in pounds,

h_1 = vertical distance (in ft. and decimal fractions) from position 1 to position 2;

h_2 = vertical distance from position 2 to position 3; and

g = acceleration of gravity (32 ft./sec.^{2})[5]

Refer to Appendix F and G for procedures and instructions on Vertical Power Jump Test.

Training Period

The training period for the three experimental groups consisted of three 30 second bouts, three days per week for six weeks. During this time Group I, control,

---

[5]Herbert A. deVries, "A Measurement of Muscle Power," Laboratory Experiments in Physiology of Exercise, (Dubuque, Iowa: William C. Brown Publishing Co., 1971), pp. 15-18.

engaged only in non-related physical activities with no weight exercises specific to the ankle-knee-hip extensors. The three experimental groups engaged in the same non-related activities and employed the same isokinetic exercise but at different controlled rates of speed. Each subject took a straddle stance directly on top of the Kinometric Contractor with her back flat against a wall brace. Refer to Figure 4. The feet remained flat on the isokinetic machine and pointed forward throughout the entire exercise movement. For maximum security and constant range of movement, the front of the foot rested squarely against a wooden support that was attached on the outer edge of the machine. The Kinometric Contractor was attached to a sturdy vertical strap suspended between the front of the legs from a nylon belt secured around the subject's waist. While assuming a half-squat position, with the back straight and feet a shoulder's width apart, a goniometer was used initially to verify the 90 degree angle position of the knee joint. Then the dip regulator was utilized to assure that this initial position was obtained with every half-squat position. Refer to Figure 5. The subject then attempted to fully stand while sustaining the given rate of speed applied and keeping the back straight and flat against the wall brace. Group II assumed the same 90 degree half-squat

Figure 4

Front View of a 90 Degree Angle and the Dip Regulator on the Kinometric Contractor

Figure 5

Side View of a Half-squat Position and the Dip Regulator on the Kinometric Contractor position previously described at a pre-set rate of speed of .8 inches per second. Group III exercised in an identical manner with a pre-set rate of 2.3 inches per second, and Group IV performed the same isokinetic exercises at the pre-set rate of speed of 3.9 inches per second. Refer to Appendix H for the subjects' score card.

EXPERIMENTAL DESIGN

Means and standard deviations were computed on the average of each pre-test power score for the initial matched groups and for the nine subjects who dropped from the study. A one-way analysis of variance was calculated on the average of each pre-test power score for the initial four matched groups and for the nine subjects who dropped from the study. The analyses of variance were utilized to determine any differences between the matched groups. An analysis of covariance was utilized on the final matched groups to determine the effect of the predetermine isokinetic speeds on the performance of leg power on the Vertical Power Jump Test and the Power Staircase Test. The Scheffe Multiple Range Test was employed to determine the nature of the specific differences in the study. A Pearson Product Moment correlation coefficient was calculated to estimate the relationship which existed between the Vertical Power Jump Test and the Power Staircase Test. A reliability coefficient was computed for both the power tests.

Chapter 4

RESULTS AND DISCUSSION

INTRODUCTION

Eighty-four non-athletic female subjects, ranging from 17 to 33 years of age, were pre-tested and post-tested on the Vertical Power Jump Test and the Power Staircase Test to determine the effect of a six-week training program on leg power. Group I represented the control group and participated in non-related physical education classes which involved no weight training exercises. The experimental groups II, III and IV, while utilizing the same isokinetic exercises, trained at the pre-set rates of speed of .8, 2.3 and 3.9 inches per second respectively. Nine subjects were dropped from the study because they did not meet for training or did not complete the post-tests. Nineteen subjects remained in Groups I, II and IV, while Group III had 18 subjects. A population description of the means and standard deviations were computed on the average of each pre-test power score for the 84 subjects matched into four initial equal groups and for the 75 subjects in the four final groups. A one-way analysis of variance was calculated on the average of each pre-test power score for the four matched groups of 21 subjects to determine any initial differences among the groups. An analysis of covariance was utilized on the final groups to determine the effect of predetermined isokinetic speeds on the performance of leg power on the Vertical Power Jump Test and the Power Staircase Test. The analyses of covariance were done by computer at Old Dominion University Computer Center. The Scheffe Multiple Range Test was employed to determine the nature of the specific differences in the study. A Pearson Product Moment correlation coefficient was calculated to determine the relationship which existed between the Vertical Power Jump Test and the Power Staircase Test. Reliability coefficients were computed between the power tests.

RESULTS

Population Description

Eighty-four non-athletic females were pre-tested on the Vertical Power Jump Test and the Power Staircase Test to determine leg power in the ankle-knee-hip extensor muscle groups. An average score was calculated from each of the two power tests, which was expressed in horsepower units. This average pre-test power score was used to initially match the subjects into four groups of 21 subjects. Table 5 shows the means and standard deviations for power scores in each of the four initial groups. Nine subjects were dropped from the study because they did not meet for training or did not complete the post-tests. Nineteen subjects remained in Groups I, II and IV, while Group III had 18 subjects.

Table 5

Means and Standard Deviations for the Power Scores of the Initial Matched Groups

Group	Number of subjects	Mean[a]	Standard deviation
I	21	.934	.239
II	21	1.047	.269
III	21	1.031	.207
IV	21	1.025	.284

[a]Power expressed in horsepower units.

Table 6 indicates the means and standard deviations for the power scores in each of the four final groups.

Table 6

Means and Standard Deviations for the Power Scores of the Four Final Groups

Group	Number of subjects	Mean[a]	Standard deviation
I	19	.961	.437
II	19	1.039	.476
III	18	1.040	.460
IV	19	1.029	.468

[a]Power expressed in horsepower units.

Effect of Matching on Group Power Scores

A one-way analysis of variance was utilized on the average pre-test score of each power test to determine the group effect of the matching on the power scores. Table 7 shows the results of the analysis of variance on the four initial matched groups based upon the average power score of the Vertical Power Jump Test and the Power Staircase Test.

Table 7

Analysis of Variance on the Four Matched Groups

Source of Variation	Degrees of freedom	Sums of squares	Mean squares	F
Treatments	3	.163	.054	.90[a]
Error	80	4.786	.060	
Total	83	4.949		

[a]4.04 was needed for significance at the .01 level.

For 3 and 80 degrees of freedom the obtained F-ratio value of .90 among the groups was not significant at the .01 level. An F-ratio of 4.04 was needed at the .01 level of significance. A complete presentation of the data is found in Appendix I.

Effect of Training on the Power Staircase Test

The analysis of covariance was utilized to determine the effect of the treatment variables on the subject's power gains. Table 8 shows the results of the analysis of covariance relative to the Power Staircase Test. For 3 and

Table 8

Analysis of Covariance on Training and Power Gains on the Power Staircase Test

Source	SS_{pre}	SS_{post}	SP	SS_y[a]	df	MS_y[b]	F
Treatments	.10	.31	.17	.09	3	.030	6.73[c]
Error	2.14	2.18	2.00	.31	71	.004	
Total	2.24	2.49	2.17	.40	74	.034	

[a]Adjusted Sum of Squares.

[b]Variance Estimates.

[c]4.09 was needed for significance at the .01 level.

71 degrees of freedom the obtained F-ratio value of 6.73 among the treatments was significant at the .01 level. An F-ratio value of 4.09 was needed at the .01 level of significance. A complete presentation of data is found in Appendix J. The Scheffe Multiple Range Test was used to determine the nature of the specific differences among the three experimental groups in terms of performance improvements on the Power Staircase Test. Table 9 shows the results of the Scheffe Multiple Range Test on the Power Staircase Test. For 3 and 70 degrees of freedom the observed differences of 18.00, 12.36 and 15.17 for Groups II-I, III-I and

IV-I respectively were significant at the .01 level. The value needed for significance at the .01 level was 12.27. The observed differences of .224, .048 and .051 for Groups II-III, II-IV and III-IV respectively were not significant at the .01 level.

Table 9

Scheffe Multiple Range Test for the Four Final Groups on the Power Staircase Test

Groups	Obtained differences[a]
Slow Speed (II) - Control Group (I)	18.00
Medium Speed (III) - Control Group (I)	12.36
Fast Speed (IV) - Control Group (I)	15.17
Slow Speed (II) - Medium Speed (III)	.22
Slow Speed (II) - Fast Speed (IV)	.05
Medium Speed (III) - Fast Speed (IV)	.05

[a]For 3 and 70 degrees of freedom a significant value of 12.27 was needed at the .01 level.

Effect of Training on the Vertical Power Jump Test

The analysis of covariance was used to determine the effect of the treatment variable on the subjects power gains.

Table 10 shows the results of the analysis of covariance on the treatments and the power gains on the Vertical Power Jump Test. For 3 and 71 degrees of freedom the obtained F-ratio value of 11.36 among the treatments was significant at the .01 level. A F-ratio value of 4.09 was needed at the .01 level of significance. A complete presentation of the data is found in Appendix J.

Table 10

Analysis of Covariance on Training and Power Gains on the Vertical Power Jump Test

Source	SS_{pre}	SS_{post}	SP	SS_y[a]	df	MS_y[b]	F
Treatments	.12	2.07	.38	1.55	3	.52	11.36[c]
Error	9.14	8.60	7.04	3.18	71	.05	
Total	9.16	10.67	7.42	4.73	74		

[a]Adjusted Sum of Squares

[b]Variance Estimates

[c]4.09 was needed for significance at the .01 level.

The Scheffe Multiple Range Test was used to determine the nature of the specific differences among the three experimental groups in terms of performance improvement on the Vertical Power Jump Test. Table 11 reveals the results of the Scheffe Multiple Range Test on the Vertical Power Jump Test. For 3 and 70 degrees of freedom the observed differences of 24.96, 16.91 and 18.74 for Groups II-I, III-I and IV-I respectively were significant at the .01 level of significance. The value need for significance at the .01 level was 12.27. The observed differences of .70, .47 and .03 for Groups II-III, II-IV and III-IV respectively were not significant at the .01 level.

Table 11

Scheffe Multiple Range Test for the Four Final Groups on the Vertical Power Jump Test

Groups	Obtained differences[a]
Slow Speed (II) - Control Group (I)	24.96
Medium Speed (III) - Control Group (I)	16.91
Fast Speed (IV) - Control Group (I)	18.74
Slow Speed (II) - Medium Speed (III)	.70
Slow Speed (II) - Fast Speed (IV)	.47
Medium Speed (III) - Fast Speed (IV)	.03

[a]For 3 and 70 degrees of freedom a significant value of 12.27 was needed at the .01 level.

Relationship Between the Vertical Power Jump Test and the Power Staircase Test

The Pearson Product Moment correlation coefficient was utilized to determine the relationship which existed between the Vertical Power Jump Test and the Power Staircase Test. Table 12 illustrates the means, standard deviations and correlation coefficient on the pre-test and post-test scores between the Vertical Power Jump Test and the Power Staircase Test. The obtained correlation coefficient values of .61 for the pre-test power scores and .64 for the post-test power scores were significant at the .01 level of significance for 73 degrees of freedom. An r-value of .29

Table 12

Means, Standard Deviations and Correlation Coefficients for Power Staircase Test and Vertical Power Jump Test

Power test	Number of subjects	Mean	Standard deviation	Correlation coefficient
Pre:				
Vertical Power Jump Test	75	1.18	.35	.61[a]
Power Staircase Test	75	.81	.17	
Post:				
Vertical Power Jump Test	75	1.30	.38	.64[a]
Power Staircase Test	75	.86	.20	

[a].29 was needed for significance at the .01 level.

was needed at the .01 level of significance for 73 degrees of freedom. The attained coefficients showed a modest correlation between the Vertical Power Jump Test and the Power Staircase Test. The means, standard deviations and correlation coefficients on the pre-test and post-test scores between the Vertical Power Jump Test and the Power Staircase Test for each final group is found in Appendix K.

A reliability coefficient was calculated on the subject's pre- and post-test power scores for the Vertical Power Jump Test and the Power Staircase Test. Table 13 depicts the results of the means, standard deviations and reliability coefficients on both the power tests.

Table 13

Means, Standard Deviations and Reliability Coefficients on the Pre- and Post-test Scores for the Power Tests

Power tests	Number of subjects	Mean	Standard deviation	r-value
Power Staircase Test:				
Pre-test	75	.81	.17	.92[a]
Post-test	75	.85	.18	
Vertical Power Jump Test:				
Pre-test	75	1.20	.36	.76[a]
Post-test	75	1.31	.38	

[a].29 was needed for significance at the .01 level.

The obtained reliability values of .92 for the Power Staircase Test and .76 for the Vertical Power Jump Test were significant at the .01 level. An r-value of .29 was needed at the .01 level of significance for 73 degrees of freedom.

DISCUSSION

The means and standard deviations in Table 5 revealed that the initial matched groups of 21 subjects each showed no significant differences for power in the ankle-knee-hip extensor muscle groups as measured by the Vertical Power Jump Test and the Power Staircase Test. This was supported by the finding in the analysis of variance on the four matched groups. For 3 and 80 degrees of freedom the F-ratio value of .90 was not significant at the .01 level. Therefore, there were no significant leg power differences among the matched groups before the start of the training period. Nine subjects were dropped from the study because they did not meet for their training session or did not complete the post-tests. Two subjects each dropped from Groups I, II and IV, while three subjects were withdrawn from Group III. Table 6 illustrated the means and standard deviations for the power scores in each of the final four groups. Group I represented the control group and participated in no weight training exercises. The experimental groups II, III and IV, while utilizing the same isokinetic exercises, trained at the pre-set rates of speed of .8, 2.3 and 3.9 inches per second respectively.

To account for any differences among the final four groups for the Power Staircase Test and the Vertical Power Jump Test analyses of covariance were computed. An examination of the post-test data provided evidence that there were significant differences among the groups for the development of power by the ankle-knee-hip extensor muscle group at the .01 level of significance. The obtained F-ratio values of 6.73 and 11.36 for the power gains on the Power Staircase Test and the Vertical Power Jump Test respectively were computed as significant values. The Scheffe Multiple Range Tests revealed that all three isokinetic training speed groups made statistically significant performance increments over the control group. No significant mean differences were shown among the three isokinetic treatments for the assessment of leg power. Previous studies by Curtis,[1]

---

[1]Richard L. Curtis, "A Comparison of the Running Speed and Leg Power Developed During a Football Season by Two Types of Specific Exer-Genie Program," (unpublished Master's thesis, California State College at Long Beach, 1969), pp. 1-51.

Testone,[2] Knight and George,[3] and Muffroid and others[4] supported these findings that isokinetic methodology does significantly improve leg power.

Several questions arose concerning the possible explanations for the lack of significant mean differences among the three isokinetic treatments for the development of leg power. Perhaps the total treatment period of six weeks was not long enough to elicit a significant training effect. Such treatments could be administered more often than three times per week and for a longer period than a total of 18 treatment periods. Another explanation might be that the total exercise period of three bouts of 30 seconds duration was not enough to produce significant differences. Exercise periods could consist of six bouts of 30 seconds. Still another possibility might be that a progressive increase in each subject's functional capacity could produce a significant training effect during the six weeks of training. The

---

[2]Angelo Testone, "The Use of Iokinetic Training to Increase the Height of the Vertical Jump," (unpublished paper, Western Illinois University, 1972), pp. 1-5.

[3]Julie Knight and Gerald S. George, "A Comparison of Isotonic Weight Training and Isokinetic Weight Training on the Development of Muscular Power," Virginia Association of Health, Physical Education and Recreation Research Journal, 1:3-7, 1972.

[3]Mary Muffroid and others, "A Study of Isokinetic Exercise," Physical Therapy, 49:735-47, July, 1969.

exercise periods could start with three bouts of 30 seconds duration and progressively increase with more or longer bouts as the subject's leg muscles required more of an overload. Previous research has revealed that the amount of work done per unit of time may be increased by increasing the load or the speed. Speed was found to be as effective as resistance for overloading the neuromuscular system.[5] Finally, another possible explanation for the lack of significant differences among the experimental isokinetic groups was that a wider variety among the rates of speed was needed.

The obtained correlation coefficients of .61 on the pre-test mean scores and .64 on the post-test mean scores between the two power tests were significant at the .01 level. These values indicated that the Vertical Power Jump Test and the Power Staircase Test had a significant, yet modest correlation when administered in the manner of this study. The obtained reliability coefficients of .92 on the pre- and post-test scores for the Power Staircase Test and

---

[5]F. A. Hellebrandt and S. J. Houtz, "Methods of Muscle Training: Influence of Pacing," The Physical Therapy Review, 38:319-326, May, 1958.

.76 on the pre- and post-test scores for the Vertical Power Jump Test were significant at the .01 level. The 81 per cent explained variance for the Power Staircase Test scores compared to the 58 per cent explained variance for the Vertical Power Jump Test indicated that the stair running test was a more reliable power test for the ankle-knee-hip extensor muscle groups. The higher reliability value for the Power Staircase Test may be accounted for by the nature of the movement involved in the stair running compared to the vertical jumping. Although the subjects performed learning trials on both the power tests before the pre-testing period, the Power Staircase Test appeared to be an easier and more natural movement than the Vertical Power Jump Test. This supported the more recent studies of Barlow[6] and Considine[7] who indicated that the vertical jump tests were limited as valid methods by which to assess true leg power.

---

[6]David A. Barlow, "Relationship Between Power and Selected Variables in the Vertical Jump," Selected Topics in Biomechanics, ed. J. M. Cooper (Chicago: The Athletic Institute, 1971), pp. 233-41.

[7]William J. Considine, "A Validity Analysis of Selected Leg Power Tests, Utilizing a Force Platform," Selected Topics in Biomechanics, ed. J. M. Cooper (Chicago: The Athletic Institute, 1971), pp. 243-250.

Chapter 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

An overview of the study is stated in this chapter. The purposes of the study, the methods employed, and the results are summarized. The conclusions of the study and recommendations for further studies are listed.

SUMMARY

The primary purpose of the study was to compare the effectiveness of three different pre-set insokinetic rates of speed on the improvement of collective muscle power in the ankle-knee-hip extensor groups. A sub-problem was to correlate two different power tests, the Vertical Power Jump Test and the Power Staircase Test and determine the reliability coefficients for each. Seventy-five non-athletic female subjects, ranging from 17 to 33 years of age, were pre-tested and post-tested on the Vertical Power Jump Test and Power Staircase Test to determine the effect of a six-week training program on leg power. The subjects were matched into four groups according to the average of each of the two pre-test scores. Group I represented the control group and participated in non-related physical education classes which involved no weight training exercises. The experimental groups II, III, and IV, while utilizing the same isokinetic exercises, trained at the pre-set rates of speed of .8, 2.3 and 3.9 inches per second respectively.

An analysis of covariance was computed on the power gains for both the Vertical Power Jump Test and the Power Staircase Test in order to determine significant mean differences among the groups. Since significant F-ratio values were found in both power tests, the null hypotheses were rejected. The Scheffe Multiple Range Test was employed to evaluate the nature of the differences among the four groups. A Pearson Product Moment correlation coefficient was also computed in order to determine the relationship existing between the power tests. Reliability coefficients were determined for each test. The .01 level of significance was chosen as the rejection point for the null hypotheses.

CONCLUSIONS

On the basis of the analysis of the data obtained within this study, the following points were concluded:

1. The three different pre-set isokinetic rates of speed significantly improved muscular power in the ankle-knee-hip extensor groups.

2. Although all three selected isokinetic speeds improved leg power, no one speed was significantly more effective than the others.

3. The Vertical Power Jump Test and the Power Staircase Test were significantly correlated for the measurement of muscular power by the ankle-knee-hip extensor muscle groups.

4. The Power Staircase Test was a more reliable measure of muscular power.

RECOMMENDATIONS

During the execution of the study, various ideas and suggestions for further study became apparent. Such suggestions make up the following recommendations:

1. A longer treatment period, with more frequent training sessions, may produce significant between-group differences.

2. A study using the Kinometric Contractor equipped with a visual force-readout gauge is recommended. It would enable the subject to evaluate his work load, functioning as a built-in motivator.

3. Power development curves shown to the subject as reinforcement should be investigated.

4. Additional studies designed to test the effects of other isokinetic speeds for the assessment of power are recommended.

5. A study is needed to investigate the effect of these isokinetic speeds on the improvement of strength, agility, endurance and other parameters.

6. Attempts should be made to investigate the validity of the Kinometric Contractor as a means of measuring power.

BIBLIOGRAPHY

BIBLIOGRAPHY

Books

Barrow, H. M., and R. McGee. A Practical Approach to Measurement in Physical Education. Philadelphia: Lea and Febiger, 1971.

Cooper, J. M. (ed.). Selected Topics in Biomechanics. Chicago: The Athletic Institute, 1971.

deVries, Herbert A. Laboratory Experiments in Physiology of Exercise. Dubuque, Iowa: William C. Brown Publishing Co., 1971.

Falls, Harold B., Earl L. Wallis, and Gene A. Logan. Foundations of Conditioning. New York: Academic Press, 1970.

Gerrish, Paul H. A Dynamic Analysis of the Standing Vertical Jump. New York: Columbia University Publishing Co., 1934.

Larson, L. A., and R. D. Yocom. Measurement and Evaluation in Physical, Health and Recreation Education. London: Henry Kempton, 1951.

Rasch, Philip J., and Roger K. Burke. Kinesiology and Applied Anatomy. Philadelphia: Lea and Febiger, 1967.

Sorani, Robert P. Circuit Training. Dubuque, Iowa: William C. Brown Publishing Co., 1966.

Weber, Jerome and David R. Lamb. Statistics and Research in Physical Education. Saint Louis: C. V. Mosby Co., 1970.

Periodicals

Anderson, T. and C. H. McCloy. "The Measurement of Sports Ability in High School Girls," Research Quarterly, 18:2-11, March, 1947.

Blish, T. C. and A. K. Scholz. "A 10-Year Survey of Physical Fitness Tests at Yale University," Research Quarterly, 28:321-26, December, 1957.

Bovard, John and Frederick Cozens. "The 'Leap-Meter,' An Investigation into the Possibilities of the Sargent Test as a Measure of General Athletic Ability," Physical Education Series, 1:19-123, June, 1928.

Collins, V. D. and S. C. Howe. "A Preliminary Selection of Tests of Fitness," American Physical Education Review, 29:63-71, December, 1924.

Councilman, James. "Isokinetic Exercise: A New Concept in Strength Building," Swimming World, 10:15, November, 1969.

________. "Isokinetic Exercise," The Athletic Journal, 53: 58, February, 1972.

Cousins, G. F. "A Factor Analysis of Selected Wartime Fitness Tests," Research Quarterly, 26:277-88, October, 1955.

Cozens, F. W. "Strength Tests as Measures of General Athletic Ability in College Men," Research Quarterly, 11:45-52, March, 1940.

Dick, Frank W. "Isokinetic Exercise," British Journal of Sports Medicine, 4:27-34, December, 1968.

Elwood, Paul M. "Stubborn Machine Helps Retain Muscle," Medical World News, September 23, 1966, p. 38.

Englehardt, J. L. "A Test of Physical Efficiency," Journal of Educational Psychology, 15:573-78, December, 1924.

Glencross, Dennis J. "The Mechanical Analysis of the Standing Broad Jump and Vertical Jump," New Zealand Journal of Physical Education, 3:29-37, July, 1964.

________. "The Nature of the Vertical Jump Test and the Standing Broad Jump." Research Quarterly, 37:353-59, October, 1966.

________. "The Power Lever: An Instrument for Measuring Muscle Power," Research Quarterly, 37:202-10, May, 1966.

Gray, R. K., K. B. Start and D. J. Glencross, "A Test of Leg Power," Research Quarterly, 33:44-50, March, 1962.

________. "A Useful Modification of the Vertical Power Jump," Research Quarterly, 33:230-35, May, 1962.

Hellebrandt, F. A. "Methods of Muscle Training: Influence of Pacing," The Physical Therapy Review, 38:319-326, May, 1958.

Hinson, Marilyn and Joel Rosentswieg. "Comparative Electromyographic Values of Isometric, Isotonic, and Isokinetic Contraction," Research Quarterly, 44:72-78, March, 1973.

Hislop, Helen J. and James J. Perrine. "The Isokinetic Concept of Exercise," Physical Therapy, 47:114-17, February, 1967.

Huffman, Walter B. and Richard A. Berger. "Comparison of Absolute and Relative Leg Power as Predictors of Physical Performance," Research Quarterly, 43:468-71, December, 1972.

Larson, L. A. "A Factor and Validity Analysis of Strength Variables and Tests with a Combination of Chinning, Dipping and Vertical Jump," Research Quarterly, 11: 82-96, December, 1940.

Latchaw, M. "Measuring Selected Motor Skills in the Fourth, Fifth and Sixth Grades," Research Quarterly, 25:439-49, December, 1954.

Johnson, Barry L. "Establishment of a Vertical Arm Pull Test (Work)," Research Quarterly, 40:237-39, March, 1969.

Kalamen, James L. "Measurement of Maximum Power in Man," Completed Research in Health, Physical Education and Recreation, 12:166, 1970.

Knight, J. and Gerald S. George. "A Comparison of Isotonic Weight Training and Isokinetic Weight Training on the Development of Muscular Power," Virginia Association of Health, Physical Education and Recreation Research Journal, 1:3-7, 1972.

Koepke, C. A. and L. S. Whitson. "Power and Velocity Developed in Manual Work," Mechanical Engineering, 62:383-89, 1940.

McCloy, C. H. "Recent Studies in the Sargent Jump," Research Quarterly, 3:235-42, May, 1932.

Margaria, R., P. Aghemo, and E. Rovelli. "Measurement of Muscular Power (Anaerobic) in Man," Journal of Applied Physiology, 21:1662-64, November, 1966.

Martin, Thomas P. and G. Alan Stull. "Effects of Various Knee Angle and Foot Spacing Combinations on Performance in the Vertical Jump," Research Quarterly, 40:324-31, May, 1969.

Morant, Charles. "A Comparison of the Exer-Genie, Isometric and Isotonic Training Programs on Selected Components of Motor Ability," Completed Research in Health, Physical Education and Recreation, 13:99, 1971.

Muffroid, Mary and others. "A Study of Isokinetic Exercise," Physical Therapy, 49:735-47, July, 1969.

Pacheco, Betty A. "Effectiveness of Warm-up Exercise in Junior High School Girls," Research Quarterly, 30: 202-13, May, 1949.

________. "Improvement in Jumping Performance Due to Preliminary Exercise," Research Quarterly, 28:55-63, March, 1957.

Perrine, James J. "Isokinetic Exercise and the Mechanical Energy Potentials of Muscle," Journal of Health, Physical Education and Recreation, 39:40-4, May, 1968.

Phillips, B. E. "The J. C. R. Test," Research Quarterly, 18:12-29, March, 1947.

Rarick, L. "An Analysis of the Speed Factor in Simple Athletic Abilities," Archives of Physical Medicine and Rehabilitation, 53:249-52, June, 1972.

Rosentswieg, Joel and Marilyn M. Hinson. "Comparison of Isometric, Isotonic and Isokinetic Exercises by Electromyography," Archives of Physical Medicine and Rehabilitation, 53:249-52, June, 1972.

Sargent, Dudley A. "The Physical Test of a Man," American Physical Education Review, 26:188-94, April, 1921.

Sargent, L. W. "Some Observations on the Sargent Test of Neuro-muscular Efficiency," American Physical Education Review, 29:47-56, February, 1924.

Start, K. B. "Measuring Power by Physical Rather Than Physical Educational Methods," New Zealand Journal of Physical Education, 23:35-37, April, 1961.

Thistle, Howard G. and others. "Isokinetic Contraction: A New Concept of Resistive Exercise," Archives of Physical Medicine and Rehabilitation, 48:279-80, June, 1967.

Van Dalen, Deobold. "New Studies in the Sargent Jump," Research Quarterly, 11:112-15, May, 1940.

Wilson, Jim. "Isokinetics for Maxi-Programs," Athletic Journal, 53:39, 91-93, April, 1973.

Unpublished Works

Curtis, Richard L. "A Comparison of the Running Speed and Leg Power Developed During a Football Season by Two Types of Specific Exer-Genie Programs." Unpublished Master's thesis, California State College at Long Beach, 1969.

Gedney, Roger H. "Effects of Generalized Cardiovascular Training on the Development of Localized Muscular Strength and Endurance." Unpublished Doctor's dissertation, Louisiana State University, 1973.

Hutinger, Paul W. "Comparison of Isokinetic, Isotonic and Isometric Developed Strength to Speed in Swimming the Crawl Stroke." Unpublished Doctor's dissertation, Indiana University, 1970.

Johnson, James H. "A Comparison of the Effectiveness of Isometric Exercises and Exercise Performed on the Kinometric Contractor in Developing Strength." Unpublished Master's thesis, Louisiana State University, 1967.

Knight, Julia P. "A Reliability Test on the Modified Dip Regulator, the Vertical Power Jump Test and the Power Staircase Test." Unpublished Pilot Study, Tidewater Community College, Portsmouth, Virginia, July, 1973.

Parsons, Robert E. "A Comparison of the Exer-Genie as a Physical Conditioning Device to Traditional Methods of Exercise." Unpublished Master's thesis, Central Washington State College, 1969.

Sterling, Leroy F. and Nicolson, Jerry. "A Comparison of Weight Training and Exer-Genie Methods of Strength Development." A paper presented at the Southern District AAHPER, New Orleans, Louisiana, March 1, 1968.

Testone, Angelo. "The Use of Isokinetic Training to Increase the Height of the Vertical Jump." Unpublished paper, Western Illinois University, 1972.

Tressel, Lea J. "The Effects of Selected Resistance Exercise Programs Upon Muscular Strength and Speed." Unpublished Doctor's dissertation, Indiana University, 1968, pp. 1-181.

Western Illinois University. Personal correspondence between Dr. Roger H. Gedney, and the writer, July, 1973.

Willson, Kent R. "The Relative Effects of Various Foot Spacings on Performances in the Vertical Jump." Unpublished Master's problem, Pennsylvania State University, 1965.

APPENDIXES

APPENDIX A

Mean Scores on Power Staircase Test for Pilot Study

Subject	Pre-test[a] X	Post-test[a] Y
1	1.632	1.728
2	1.257	1.321
3	1.372	1.325
4	2.091	2.205
5	1.564	1.733
6	1.338	1.516
7	1.573	1.629
8	1.601	1.617
9	1.345	1.445
10	2.041	1.997
11	1.502	1.513
12	1.682	1.725
13	1.590	1.726
14	1.303	1.431
15	1.276	1.406
16	1.445	1.503
17	1.382	1.413
18	1.473	1.615
Mean	1.526	1.603
Standard deviation	.235	.226

[a]All scores are reported in horsepower units.

APPENDIX B

Mean Scores on Vertical Power Jump Test for Pilot Study

Subject	Pre-test[a] X	Post-test[a] Y
1	1.50	1.48
2	2.07	2.06
3	1.47	1.47
4	1.96	1.97
5	2.23	2.09
6	2.41	2.56
7	1.83	1.79
8	2.16	2.28
9	1.53	1.57
10	2.20	2.09
11	2.14	2.20
12	1.85	2.12
13	2.47	2.38
14	1.76	2.19
15	1.91	1.75
16	1.90	1.81
17	2.71	2.38
18	1.58	1.73
19	2.71	2.18
Mean	2.02	2.01
Standard deviation	.378	.312

[a]All scores are reported in horsepower units.

APPENDIX C

Mean Scores on Modified Dip Regulator for Pilot Study

Subject	Pre-test[a] X	Post-test[a] Y
1	19.00	18.00
2	20.00	20.25
3	17.00	17.00
4	20.25	20.25
5	19.50	19.50
6	17.75	18.00
7	18.00	18.00
8	18.25	18.00
9	21.00	20.00
10	19.50	19.25
11	19.00	19.00
12	18.50	18.75
13	21.00	21.00
14	20.00	18.25
15	19.75	19.00
16	18.25	18.25
17	18.25	19.00
18	16.75	16.50
19	18.50	18.50
Mean	18.961	18.763
Standard deviation	1.211	1.132

[a]All scores are reported in inches.

APPENDIX D

Procedures for the Power Staircase Test

1. Seventy-five female subjects were tested for their maximum leg power on a solidly constructed staircase consisting of 7 units of 2 steps per unit. An electric clock sensitive to .001 seconds was used to time the subjects as they individually ascended the stairs.
2. Instructions were given to each subject and a demonstration was performed by an assistant to avoid any confusion. Any questions were answered prior to the test as an aid to the subject's complete understanding.
3. Each subject took a square position behind a strip of tape placed six feet in front of the first step. Whenever she was ready, the subject started her run up the stairs at maximum speed, taking one unit at a time. On the second and sixth unit, the subject contacted rubber pads which were attached to the electric clock. The subject's weight automatically started and stopped the clock as her foot touched the sensitive pads. The subject was cautioned that she must not stop on the stairs and must put forth her maximum effort from the start to beyond the last step.

4. The clock recorded the subject's speed from the second to the sixth unit which timed the vertical rise of 4 units with the total height of 4.88 feet. Each subject performed the Power Staircase Test three times, with short rest periods intervening to minimize any fatiguing effect.

5. The muscular power was calculated by dividing the mean from the three trial runs into the subjects weight times the total step height. The results were expressed in foot pounds per second and finally converted into horsepower units.

APPENDIX E

Instructions for Subjects Performing the Power Staircase Test

1. You are to perform a simple task of running up seven steps to determine your maximum leg power. (1 step = 2 normal stairs)

2. Power is defined as work/time or the amount of time it takes to perform a given task. You are going to undergo a certain degree of work which will be timed by an electric clock. It is important to produce your maximum speed throughout the entire test so that your recording time will be as fast as possible. You are racing against the second hand!

3. You are to begin the test by taking a SQUARE STANCE behind a strip of tape placed on the floor 6 feet in front of the staircase. These six feet will allow you to sprint and build-up your speed before taking the first marked step.

4. Whenever you are ready you may begin your climb taking one step at a time. Be certain to hit the black rubber pads found on the 2nd and 6th step. As soon as you hit the first rubber pad, the clock begins and will stop as you step on the second rubber pad.

5. DO NOT STOP ON THE STAIRS! Touch the wall at the top of the stairs.

6. Observe closely the demonstration to be given by the assistant. Keep in mind two main factors:

   (1) From a square stance take one step at a time hitting the desired rubber pads.

   (2) Put forth your BEST effort for the FASTEST time possible.

7. Are there any questions concerning the procedures of the request made of you?

8. Please be seated in the adjacent waiting room until you are called for your trials.

APPENDIX F

Procedures for the Vertical Power Jump Test

1. Seventy-five female subjects were tested for their maximum leg power on a vertical jump. A dip regulator was used to assure that the subject initiated her jumps from a 115 degree angle at the knees.
2. Instructions were given to each subject and a demonstration was performed by an assistant to avoid any confusion. Any questions were answered prior to the test to aid in the subject's complete understanding.
3. Each subject's weight was recorded to the nearest half pound. Following a one minute warm-up of running in place to a metronome, the subject was instructed to take a lateral foot spacing of 7 inches, which was marked clearly with tape, beside the jump board. One hand was secured behind the back while the preferred arm was raised vertically and held steadily against the side of the head. While keeping the head and back erect, the subject dipped until the appropriate knee angle of 115 degrees was attained as measured by the goniometer. She was instructed to maintain that position while the dip

bar was placed under her buttocks and the first chalk mark was made by her extended fingertips. This mark was labeled position 1. The subject then stood on her tiptoes in the same sideway position and attempted to reach as high as possible. A second chalk mark was made at that point and labeled position 2. Keeping the same body position, the subject dipped until her buttocks just touched the dip regulator. When the subject was ready she jumped upward putting forward her maximum effort and marking her highest point of the jump with her chalked fingertips. This mark was labeled position 3. Each subject performed three trials of the Vertical Power Jump Test, with short rest periods between each trial to prevent any fatiguing effects.

4. The vertical difference in height was calculated from the average of the three chalk marks in position 1 to that of position 2 and from the average chalk mark between position 2 and position 3. Power was determined by using the following formula:

$$\text{Power (in hp)} = \frac{w\ (h_1 + h_2)}{550\ h_1} \quad X \sqrt{\frac{gh_2}{2}}$$

where w = body weight in pounds,

h_1 = vertical distance from position 1 to position 2;

h_2 = vertical distance from position 2 to position 3;

g = acceleration of gravity (32 ft./sec.^{2})

APPENDIX G

Instructions for Subjects Performing Vertical Power Jump Test

1. You are to perform the simple task of jumping upward for determining your maximum leg power.

2. Power is defined as work/time or the amount of time it takes to perform a given task. You are going to undergo a certain degree of work which will be measured by the height in which you are able to jump from a squatting position. It is important to produce your MAXIMUM effort throughout the test so that your jump will be measured to the half of an inch.

3. First, you will be weighed minus shoes and socks. Secondly, you are to warm-up by running in place to the beat of the metronome. Thirdly, you are to chalk your fingertips and take a standing side position next to the jump board, as indicated by the taped squares on the floor. Fourthly, place one hand behind your back while raising your preferred arm straight up and steady against the side of your head. Maintain this position throughout the ENTIRE test.

4. While keeping your head and BACK erect, you are to squat until the instructor asks you to stop. While squatting touch the jump board with your extended chalked fingertips.

5. Next you are to stand on your tiptoes in the same sideways position with the back, head, feet and arms in the same position. Attempt to reach as high as possible and then touch the jump board with your extended chalked fingertips.

6. Keeping the same body position, squat down until the instructor tells you to stop. When you are ready, jump upward putting forward your BEST effort and touch the jump board at the PEAK of the jump with your chalked fingertips.

7. Observe closely the demonstration to be given by the assistant. Keep in mind two main factors:

   (1) Maintain the SAME body position throughout the jump.

   (2) Put forth your BEST effort for the HIGHEST jump possible.

8. Are there any questions concerning the procedures of the request made of you?

9. Please be seated behind the screen until you are called.

APPENDIX H

SUBJECT'S SCORE CARD

COMPARISON OF KINOMETRIC EXERCISES AT THREE DIFFERENT PRE-SET RATES OF SPEED FOR POWER GAINS

NAME ______________________ GROUP ______________________

PHONE ______________________ SCHEDULE TIME ______________________

ADDRESS ______________________ PRE-TEST WEIGHT ______________________

______________________ POST-TEST WEIGHT ______________________

WEEKS	MONDAY	WEDNESDAY	FRIDAY	PARAMETER	PRE-TEST	POST-TEST	GAINS
1				VERTICAL POWER JUMP TEST			
2				POWER STAIRCASE TEST			
3							
4							
5							
6							

AVERAGE POWER TEST SCORE ______________

VERTICAL JUMP KNEE ANGLE __________ (115°)

ISOKINETIC KNEE ANGLE ____________ (90°)

PRE-TEST TIME ______ POST-TEST TIME ______

APPENDIX I

The Average Pre-test Mean Scores of Each Power Test for Each Subject in the Four Initial Matched Groups

Subject	Groups I	II	III	IV
1	.779	.730	.755	.675
2	.702	.691	.909	1.068
3	.879	.709	.819	1.728
4	.659	.751	1.137	1.102
5	.986	1.045	.931	1.149
6	.882	1.014	.902	.894
7	.836	1.164	.833	.967
8	.938	.655	.970	1.012
9	.733	.898	1.022	.859
10	1.090	.945	.749	1.043
11	1.061	1.089	1.036	1.159
12	.720	1.262	1.127	1.255
13	1.287	.921	1.160	1.245
14	.705	1.132	1.348	.892
15	1.193	1.043	1.422	1.079
16	.995	1.460	1.441	.744
17	1.192	1.381	1.325	1.023
18	1.009	1.771	.829	.558
19	1.604	1.082	.895	1.111
20	1.157	1.125	.919	.880
21	1.096	1.124	1.119	1.074
Mean	.934	1.047	1.031	1.025
Standard deviation	.239	.269	.207	.234

[a]All scores are reported in horsepower units.

APPENDIX J

Pre-test and Post-test Scores

The Pre-test and Post-test Mean Scores of Each Subject in the Control Group for the Vertical Power Jump Test and the Power Staircase Test[a]

Subject	Vertical power jump test		Power staircase test	
	X	Y	X	Y
1	.843	.966	.714	.656
2	.755	.660	.649	.378
3	.894	.904	.864	.865
4	.760	.605	.557	.544
5	1.135	1.096	.837	.838
6	1.037	1.216	.727	.714
7	.927	.796	.744	.728
8	1.135	1.187	.741	.730
9	.830	.858	.635	.620
10	1.170	1.093	1.010	1.055
11	1.192	1.213	.930	.872
12	.864	.738	.575	.547
13	1.672	1.707	.901	.877
14	.788	.570	.622	.654
15	1.447	1.205	.938	.865
16	1.217	1.026	.773	.768
17	1.697	.853	.686	.725
18	1.330	1.131	.687	.725
19	2.257	1.698	.950	.925
Mean	1.16	1.03	.77	.74
Standard deviation	.39	.32	.14	.16

[a]All scores are reported in horsepower units.

APPENDIX J (continued)

The Pre-test and Post-test Mean Scores of Each Subject in Group II for the Vertical Power Jump Test and the Power Staircase Test[a]

Subject	Vertical power jump test X	Vertical power jump test Y	Power staircase test X	Power staircase test Y
1	.694	1.006	.823	.843
2	.639	.892	.765	.797
3	.725	.781	.743	.801
4	.818	1.157	.692	.792
5	1.267	1.395	.683	.743
6	1.318	1.383	.709	.783
7	1.319	1.482	1.009	1.058
8	.745	1.106	.564	.613
9	1.218	1.526	.578	.687
10	1.139	1.259	.750	.817
11	1.389	1.482	.788	.905
12	1.626	1.508	.898	.967
13	1.102	1.278	.739	.767
14	1.282	1.651	.981	1.052
15	1.397	1.528	.688	.736
16	1.590	1.852	1.329	1.408
17	1.940	1.826	.822	.930
18	2.214	2.719	1.327	1.344
19	1.371	2.005	.793	.793
Mean	1.25	1.47	.83	.88
Standard deviation	.42	.44	.21	.21

[a]All scores are reported in horsepower units.

APPENDIX J (continued)

The Pre-test and Post-test Mean Scores of Each Subject in Group III for the Vertical Power Jump Test and the Power Staircase Test[a]

Subject	Vertical power jump test		Power staircase test	
	X	Y	X	Y
1	.726	1.511	.784	.900
2	.919	1.197	.899	.932
3	.899	1.174	.738	.747
4	1.284	1.617	.989	1.049
5	1.073	1.240	.789	1.002
6	.976	1.133	.828	.786
7	.993	1.331	.673	.767
8	1.117	1.201	.822	.797
9	1.354	1.472	.690	.751
10	.921	1.150	.577	.703
11	1.308	1.246	.764	.802
12	1.295	1.159	.959	1.010
13	1.328	1.687	.991	1.079
14	1.663	1.604	1.033	.945
15	1.601	1.786	1.242	1.332
16	1.814	1.586	1.067	1.105
17	1.560	1.356	1.089	1.055
18	1.046	1.302	.611	.620
Mean	1.22	1.38	.86	.91
Standard deviation	.30	.21	.18	.18

[a]All scores are reported in horsepower units.

APPENDIX J (continued)

The Pre-test and Post-test Mean Scores of Each Subject in Group IV for the Vertical Power Jump Test and the Power Staircase Test[a]

Subject	Vertical power jump test		Power staircase test	
	X	Y	X	Y
1	.750	.931	.600	.642
2	1.182	1.296	.953	.971
3	.769	.726	.687	.789
4	1.186	1.089	1.017	.938
5	1.409	1.983	.888	.830
6	.969	1.216	.819	.965
7	1.019	1.314	.914	.926
8	1.099	1.531	.924	1.016
9	.990	.990	.728	.743
10	1.330	1.536	.756	.878
11	1.424	1.380	.894	.911
12	1.544	1.748	.965	1.029
13	1.527	1.710	.962	.933
14	1.084	1.753	.700	.826
15	1.263	1.664	.894	.996
16	.914	1.097	.574	.495
17	1.356	1.601	.690	.916
18	.541	.572	.573	.709
19	1.721	1.432	.500	.601
Mean	1.16	1.37	.79	.85
Standard deviation	.30	.38	.16	.15

[a]All scores are reported in horsepower units.

APPENDIX K

The Means, Standard Deviations and Correlation Coefficients on Pre-test and Post-test Between the Two Power Tests for Each Final Group

Power test	Vertical power jump test		Power staircase test		Correlation coefficient
	Mean	Standard deviation	Mean	Standard deviation	
Pre:					
Group I	1.10	.38	.76	.14	.67[a]
Group II	1.25	.42	.83	.21	.65[a]
Group III	1.22	.30	.86	.18	.73[a]
Group IV	1.16	.30	.79	.16	.35
Post:					
Group I	1.03	.31	.74	.16	.68[a]
Group II	1.47	.44	.88	.21	.66[a]
Group III	1.38	.21	.91	.18	.66[a]
Group IV	1.34	.38	.86	.14	.55

[a]Significant at the .01 level.