A COMPARISON OF A TRUE MEASURE OF LEG MUSCULAR POWER AS DETERMINED BY A PHOTO-ELECTRIC SYSTEM TO FIVE CONVENTIONALLY USED TESTS OF LEG MUSCULAR POWER

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BY

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ABSTRACT

This study was done to determine the validity of five conventionally used tests of leg muscular power, namely, the Modified Vertical Jump, Standing Broad Jump, Ten Yard Sprint with Five Yard Running Start, Fifty Yard Sprint with Five Yard Running Start, and Bicycle Ergometer Speed Test. The criterion measure of leg muscular power which enabled the researcher to determine the validity of the conventional tests by statisically determining their relationship to the criterion measure was a mechanical device with a photo-electric timing system. This technique supplied the necessary information to determine the power output using the physical sciences' formula for that entity.

The sample (N = 42) was subjected to each of the five conventional tests as well as the criterion measure. In addition to these tests, the age and weight of each subject was obtained.

Pearson Product Moment Correlation Coefficients were employed in the statistical analysis of the data. Insignificant correlations were obtained between the criterion measure of leg power and each of the five conventional tests of leg power. However, when the five conventional tests were compared to power per pound body weight, the correlation coefficients were significantly higher than those obtained from the comparision of each of the conventional tests to the total maximum power, but, these too remained insignificant at the .01 level. It was also found that the average maximum power output occured at 45 percent of

the subject's maximum lift, however, the optimum point ranged between 29 percent and 53 percent.

It was concluded that, (1) the conventionally used tests of leg power were not valid measures for determining the subject's power output; (2) the five conventional tests were better indicators of power per pound body weight than they were indicators of the total maximum power output, however, the correlation coefficients were still insignificant and therefore did not justify the use of these tests to determine the ability of the legs to develop power, and (3) the average optimum load which yielded the maximum power output was 45 percent of the subject's maximum lift.

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CHAPTER I

INTRODUCTION

Need for the study:

A number of athletic performances have been regarded as power events. This has been true of most track and field events; the sprints, the jumps, and the throws have all been recognized as events that demonstrate maximum muscle contraction over a minimum period of time. It then followed that the entity, power, be considered as an important basic component of motor performance with respect to the above stated events. While there was no disagreement with this concept in past research there was tremendous controversy over the issue of how to measure muscular power. Power has been defined by the physical sciences as being equal to the product of force times velocity, or more specifically, force times distance divided by the time. With these definitions in mind, one must consider the actual tests for measuring muscular power. Four of the most commonly used tests of leg muscular power have been:

(1) Sargent Jump or some modified version of it
(2) Standing Broad Jump
(3) Some Type of Sprint Test
(4) Bicycle Ergometer Speed Test

None of the above tests have been used to give a direct or absolute measure of power, but the unit of measurement used- whether it was in inches jumped, seconds, or number of revolutions- was supposedly a measure of muscular power, that meant that the person who jumped the farthest or ran the fastest must have been the most powerful person.

Whatever the reasoning, these tests have been regarded as indicators of an individual's ability to develop power. However, these tests have been incorrectly justified for they have not conformed to the physical sciences' definition of power as the rate of doing work. Thus, muscular power should be defined as the rate of performing muscular work and the forementioned commonly used tests should not be regarded as valid measures.

Past research has both upheld and contradicted the opinion that the four conventional tests quoted earlier have been good indicators of muscular power. The primary reason for this was that muscular power has been considered such a complex entity that it has not lent itself to easy measurement. Few devices have been developed to accurately measure muscular power and even they were questionable. Therefore, researchers have relied on popular opinion as criterion values by which to determine the validity of the tests of muscular power. It was then of the utmost importance to devise a method that enabled the accurate measurement of muscular power and thus make possible the assessment of the conventionally used tests of muscular power.

The problem:

This investigation was conducted to determine the validity of selected tests as measures of leg muscular power. The criterion measure for assessing true leg power had to be derived by adhering to the physical sciences' definition of power. Therefore, before the validity of the selected tests could be determined, a device had to be constructed which gave a true measure of muscular power. It was also necessary to determine the optimum load which yielded maximum power output before the selected tests could be compared to the criterion measure.

The conventional leg power tests selected for comparison to the criterion measure were:

(1) Modified Vertical Jump
(2) Standing Broad Jump
(3) Ten Yard Sprint with Five Yard Running Start
(4) Fifty Yard Sprint with Five Yard Running Start
(5) Bicycle Ergometer Speed Test

Correlation coefficients indicated the relationship between each independent test variable and the dependent criterion variable to determine the validity of the selected tests as measures of leg power.

Hypothesis:

There is no significant correlation between a true measure of leg muscular power and each of the following five conventionally used tests of leg muscular power: Modified Vertical Jump; Standing Broad Jump; Ten Yard Sprint with Five Yard Running Start; Fifty Yard Sprint with Five Yard Running Start, and Bicycle Ergometer Speed Test.

$rxy < .3848$* (.01 level of significance)

Where:

r = Pearson Product Moment Correlation Coefficient
x = True Measure of Leg Muscular Power
y = Conventional Test Used to Measure Leg Muscular Power

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

Limitations of the study:

(1) The weights on the universal gym machine were given in twenty pound increments, therefore, it was not always possible to use the appropriate weight. For example, if the subject's maximum lift was four hundred sixty pounds and he had to be tested at twenty percent of his maximum, a ninety-two pound weight should have been used. However, the limitation of the equipment used necessitated the use of a hundred pound weight instead of the appropriate ninety-two pound weight. The various weights used, however, were always within ten pounds of the appropriate weight.

(2) To determine the subject's power output, the weights on the universal gym machine had to be used. Unfortunately, the units of measure were given using the Imperial System rather than the newly adopted Metric System. This necessitated that the paper be written using the Imperial Units of measurement since the researcher felt that the use of any conversion factor would produce error in determining the true measure of power output.

(3) Because of the extended period of time needed to test each subject, testing times were not held constant. The numerous testing times were arranged so that they were convenient for the subject. Therefore, the diurnal variation in strength was not considered in this study.

Basic assumptions:

It was assumed by the experimenter that the technique used to determine the true measure of power output of the subject was a valid and reliable measure of power since it adhered to the physical sciences' definition of power. Also, that each subject's maximum power output was found by the use of the same technique, and that the time of testing had no significant effect upon the results obtained.

The knee angle for all subjects - in the starting position - was constant between sixty-five and seventy-five degrees. It was assumed that this difference had no significant effect on the results.

Definition of terms:

TABLE I

FORMULA FOR PHYSICAL SCIENCES' DEFINITION OF POWER

$$P = \frac{F \times D}{T}$$

P = Power

F = Force

D = Distance travelled by force F

T = Time

Photo-Electric System.....A mechanical system with a photo-electric timing device that was devised by the experimenter to obtain each subject's true power output.

Optimum Power.............The maximum power output achieved by the subject.

Velocity..................The rate of motion. In this study, it was equated with speed and consisted of the $\frac{\text{distance}}{\text{time}}$ component of the physical sciences' definition of power.

Strength..................The force component of the physical sciences' definition of power. In this study, it was equated with the weight moved.

Universal Gym Machine.....A machine which consisted of weights, levers and pulley systems that were arranged such that they allowed an individual to perform various movements with a desired resistance for weight training purposes.*

Maximum Lift..............The smallest weight to the nearest ten pounds which cannot be lifted a distance of fourteen inches.

Muscular Power............The component of physical performance which can be defined as the rate of doing work.

Staggered Position........A stance adopted by the subject whereby he stood in an upright position with one foot in front of the other.

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*Designed by: Universal Athletic Sales Company, 4707 E. Hedges Avenue, Fresno, California 93703

CHAPTER II

REVIEW OF LITERATURE

A review of the available measures of muscular power failed to reveal a test of the specific nature required. Of those that have been used, not one has had the distinction of being able to determine the optimum load for maximum power development, that is, the percentage of maximum lift which yields the greatest power output. Therefore, a test of true power had to be developed which formed the basis of this paper, in other words, a standard by which to test the validity of the conventionally used tests of muscular power.

Two studies, one by Glencross (6) and the second by Considine (4) tried to develop devices for measuring muscular power using the physical sciences' definition. Glencross devised a power lever which consisted of a handle, a lever arm, three microswitches and a pulley with a steel rope. The resistance against which the body exerted its effort was supplied by known weights that were attached to the steel rope. The handle attached to the lever arm was the means by which the body or limb was attached to the power lever. Microswitches started and stopped two Relion chronoscopes and made possible the timing of the movement through a set arc which the handle moved.

However, Glencross's power lever was restricted to one body segment or limb at a time. Yet, in any of the conventional tests of leg muscular power, both legs are used. Therefore, it was felt that this device could not be used as the criterion measure to determine leg muscular power.

Considine's (4) means of measuring leg muscular power utilized a force platform. In this technique, the force was the weight of the man; the time was the time the force was applied and, the distance was the height jumped. However, this device was not sufficient to determine the optimum load for maximum power output since the only load tested was the subject's own weight. Considine used his device to test the validity of the (a) Vertical Jump and Reach; (b) Standing Broad Jump; (c) Chalk Board Jump; (d) Five Yard Sprint; (e) Ten Yard Sprint, and (f) The Running Five Yard Sprint with a Five Yard Running Start, as tests of leg power. He found that all correlation coefficients except the Five Yard Sprint were significant enough to justify the conclusion that they were valid tests of leg muscular power.

In consideration of past research, it was found that the conventional tests of leg muscular power fell into four catagories. Firstly, there was the Sargent Jump or some modified version of it; secondly, the Standing Broad Jump; thirdly, the Sprints and lastly, various speed tests of movement or reaction time.

McCloy (12) compared the Sargent Jump to four track and field events. His assumption was that since track and field events were 'power' events, then if the Sargent Jump was a valid test of leg power, it should correlate highly with the four tests. From his results, McCloy concluded that, " The Sargent Jump, when standardized, practiced and correctly administered was undoubtedly a valuable test for predicting the ability to develop power." 1

Van Dalen(18) in a later study used the same technique as McCloy in comparing the same four track and field events to six different types of the Vertical Jump. Not surprisingly, he arrived at the same conclusion as McCloy.

It was the consensus of the above authors that the original work which led to the development of tests for power was done by D. A. Sargent(13). Sargent was primarily interested in developing some type of performance test which would enable one to assess the physical efficiency of man. It was not his intent at the time to design a test which could be claimed to measure a specific component of physical performance. Nevertheless, the Sargent test quickly gained prominence and its original purpose became somewhat obscure. This obscurity resulted from the investigations of L. W. Sargent(14) and C. H. McCloy(12) who stated the Sargent Jump was a good test of muscular power. Since that time many variations of the original Sargent Jump have been devised and either accepted or rejected as tests of muscular power.

The fault of the research quoted above was that there was no criterion to which the conventional tests of muscular power could be compared. Assumptions were made to the effect that track and field events were principally events of muscular power. It was not noted that these events also incorporated many other components of physical performance and, therefore, should not have been used as the criterion value.

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[1] C. H. McCloy, "Recent Studies in the Sargent Jump," The Research Quarterly, 3: 241, May, 1932.

Three studies, however, did try to develop a criterion value based on the physical sciences' definition of power. In a study by Gray, Start, and Glencross(9), a test of Vertical Leg Power was devised and validated by the use of a formula derived from the physical sciences' definition of power. This so-called Modified Vertical Jump was determined a valuable test of muscular power. Unfortunately, it too considered power using only one load.

Considine(4), as stated earlier, devised a force platform from which he obtained a criterion measure by which to test the validity of six conventional tests of muscular power, namely, the Vertical Jump and Reach; the Standing Broad Jump; the Chalk Board Jump; the Five Yard Sprint; the Ten Yard Sprint, and the Five Yard Sprint with the Five Yard Running Start. He found that neither of the tests were justifiable measures of muscular power.

Glencross(6), like Considine, used his device, the power lever, as his criterion measure of power. He compared two conventionally used tests of power - the Jump and Reach test and the Standing Broad Jump, to his criterion. He found that both tests had very limited applications as measures of muscular power.

Because of the sudden trend to approach the problem of whether or not conventional tests of muscular power were valid measures, researchers began adhering to the physical sciences' definition of power. As a result, much controversy arose as to which of the components of muscular power was most important. In a study by Berger and Henderson(2) it was found that strength or force correlated highly with power. Yet, many other studies (5, 11) reported that strength was not the primary component of power. Two studies, one by Gray, Start, and Walsh (10) and the second by Start et al (17) even stated that speed or velocity was the primary component. Gray, Start, and Walsh's reasoning that speed was most important was based on their experiment involving a Bicycle Ergometer Speed Test. In their experiment they correlated the Bicycle Ergometer Speed Test with the Vertical Power Jump which was supposedly a true measure of muscular power. The results supported the hypothesis that there was a significant correlation between the two variables. The Bicycle Ergometer Speed Test was devised because it was felt that there was no test which accurately measured speed. The only speed tests used before this study were the various Sprint tests, but it was felt that the Sprint tests involved too many uncontrollable variables such as: length of stride, mechanical efficiency, and running technique. The Bicycle Ergometer Speed Test eliminated all of these variables. In the test, the subject's speed was determined by the number of revolutions of the bicycle wheel in a given period of time.

In summary, previous research papers offer conflicting evidence as to whether or not the conventional tests were valid measures of muscular power. In some cases, they have been accepted or rejected based on their correlation with a non-justifiable criterion. In other cases, a criterion or true measure of power was devised, but they too, had two serious drawbacks and could not be justifiably claimed as valid criterion measures. Firstly, although they did accurately measure power, they were not suitable criterion measures because of their failure either to obtain the optimum power output or to consider both legs in testing for leg muscular power since both legs were used in all of the conventional tests for leg muscular power. Secondly, in obtaining their criterion measure, no study considered the effect of fatigue.

CHAPTER III

METHODOLOGY

Research design:

All subjects were placed in one sample and given six tests of leg muscular power, one test being the criterion measure and the other five tests were conventionally used tests of leg muscular power. In addition to administering the six power tests, the age and weight of each subject were recorded.

Sample selection:

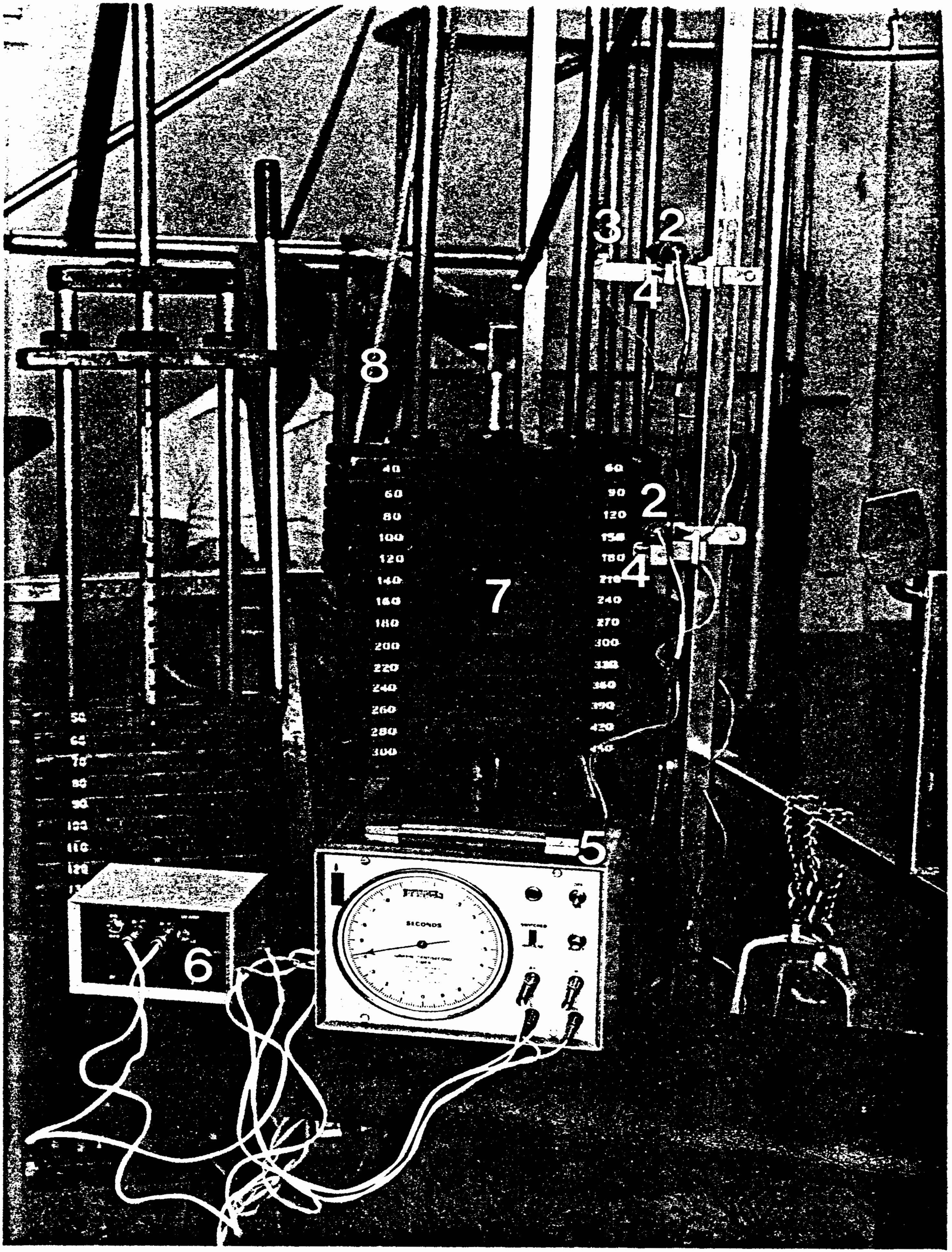
Subjects($N = 42$), ranging from eighteen to twenty-four years of age, were chosen from second and third year physical education students at Memorial University. For this study, two classes were opportunity selected and all male students were tested. The sample was discriminatory in that all subjects were male, but it was felt that this was necessary to avoid any influence the sex variable might have on the results.

Description of apparatus:

Photo-electric system:

1 ....two 'Y' shaped metal supports
2 ....two light sources
3 ....two photo-electric cells
4 ....four metal clamps

FIGURE I



3
2
4
8
40
60
80
100
120
140
160
180
200
220
240
260
280
300
2
4
7
5
SECONDS
6

5 ....electronic timer

6 ....control box

7 ....universal gym machine

8 ....rope

For this study, a photo-electric system was constructed to determine the speed of movement of a given weight. Reference is made to a picture of the apparatus which was attached to an universal gym machine. The apparatus consisted of two Y-shaped supports attached to a vertical metal pole of the universal gym machine. On one end of the support was attached a light source and at the other end was attached a photo-electric cell. The same was done with the second Y-shaped metal support. The distance between the light source and the cell was sufficient to allow the weights, for the leg extension movement, to pass between them. Both lights and photo-electric cells were wired into a control box. The control box was connected to an electronic timer. The system worked such that when it was not in use, the circuit was not broken since each light beam was focused on its corresponding photo-electric cell. However, when the subject sat in the chair, placed his feet on the proper metal plates, and extended his leg thus elevating the weights, the first light beam was broken and the electronic timer was started. As the weight kept moving up, it broke the second light beam thus stopping the timer. This device and the physical sciences' definition of power enabled the experimenter to determine the power output of the subject.

$$\text{Power} = \frac{\text{Force x Distance}}{\text{Time}}$$

Where: Force = the weight moved.

Distance = the distance between the two photo-electric cells(1.166 feet).

Time = the time it took the subject to move the weight over the given distance, which was recorded on the electronic timer

Testing procedure:

Null hypothesis: There is significant correlation between a true measure of leg muscular power and each of the following five conventionally used tests of leg muscular power: (a) Modified Vertical Jump; (b) Standing Broad Jump; (c) Ten Yard Sprint with Five Yard Running Start; (d) Fifty Yard Sprint with Five Yard Running Start; (e) Bicycle Ergometer Speed Test.

$$rxy \geq .3848_{(19)} \text{ (.01 level of significance)}$$

Each subject was tested to determine his optimum load, that is, the weight that would yield the greatest power output. This problem was solved in a previous study which tested ten subjects on their full range, that is, from ten to ninety percent of their maximum lift. For example, if the subject's maximum lift was four hundred pounds, then he was tested using weights of forty, eighty, one hundred twenty, one hundred sixty, two hundred, two hundred forty, two hundred eighty, three hundred twenty, and three hundred sixty pounds. The subject's power output was determined using the physical sciences' definition of power. However, the weights on the universal gym machine were in increments of twenty pounds, therefore, the subjects could not always be tested with the appropriate weight. For example, if the subject's maximum lift was four hundred sixty pounds, a forty-six pound weight was necessary to test him at ten percent of his maximum. However, a forty pound weight had to be used since this was the increment nearest in weight to the actual weight necessary at ten percent of subject's maximum lift. Nevertheless, all testing was done to within ten pounds of the appropriate weight.

The average percentage of maximum load which yielded the greatest power output for the subject was 45 percent, with a range from 29 percent to 53 percent.

Each subject had three trials at each ten percent increment, with one half minute rest between each trial. The resting time between each set of three trials was two minutes. A longer period for resting time was not given between each trial because it was felt that it was important that the subject realize just how much weight he had to push to obtain maximum speed of leg extension. The ten percent increments were given in random order in the following order: (a) ninety percent; (b) twenty percent; (c) seventy percent; (d) ten percent; (e) fifty percent; (f) sixty percent; (g) thirty percent; (h) eighty percent; (i) forty percent. Ninety percent of maximum lift was chosen to be the criterion to test for local muscular fatigue, that is, the subject's fastest time in moving this weight was recorded, the test administered, and the ninety percent weight again used to see if the times before and after the test were significantly different, thereby, denoting fatigue.

A student T-test [1] was used to determine if there was a local muscular fatigue factor. It was found that there was no significant difference between the speeds of movement at the .01 level of significance ($T = -.833$).[2]

For this study, to ensure that the optimum load was within the acquired range from the previous study, ten percent on either side of the range was included in the testing. Thus, all subjects were tested from twenty through sixty percent of their maximum lift.

Firstly, all subjects were tested for maximum lift. In order to arrive at this weight with as few trials as possible, each subject started at four hundred pounds and worked up or down in twenty pound increments depending on whether or not he was able to move the weight. The maximum lift was recorded as the smallest weight the subject could not lift.

Before testing, all subjects recieved a one minute general warm-up which consisted of running on the spot as well as a series of five leg extension trials using a variety of weights. This last warm-up was necessary, not only to warm up the specific muscles involved in the test, but also to allow the subject to become familiar with the testing procedure.

In the test, all subjects were tested using the twenty through sixty percent range of maximum lift in random order. Each subject

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[1] See Table XIII, p. 73.

[2] Need 2.10 at the .05 level.

repeated each increment three times with a one minute rest interval between trials and a five minute rest interval between each set of trials. This extended time was added precaution against any possibility of local muscular fatigue. It was noted in the previous study that at very low weights the subject's feet would leave the metal plates after a full and forceful extension of his legs. Since the subject's feet could not be strapped to the plates because of the possibitity of injury to the subject from the abrupt finish, it was necessary to use a rope which prevented the sudden recoil of the metal plates when the weights returned to the starting position.

To ensure that all subjects had equal mechanical advantage when seated in the leg extension chair with their feet placed on the metal plates, a protractor was used to standardize the angle at the knee. Since the chair could be moved closer to or away from the metal plates, it was possible to keep the knee angle consistently between sixty-five and seventy-five degrees.

All subjects were instructed to keep their backs against the back of the chair with each hand gripped around the metal rods protruding from the seat. All subjects wore shorts, t-shirts and running shoes. Verbal instructions were also given during the trial. Each subject was told to extend his legs as forcefully and quickly as possible. This last instruction was repeated prior to each trial.

Even though the distance between the photo-electric cells was 1.165 feet, it was sufficient enough to test the movement time over a full range of movement beginning with the sixty-five to seventy-five degree knee angle and ending just before the subject reached his full extension of his legs.

The above criterion was then compared to the five conventionally used tests of leg power to determine their validity. Firstly, the Modified Vertical Jump used in this study was described by Gray, Start, and Glencross(8). They found it to be superior to the Jump and Reach test and the Squat Jump test, and that it was a good test of leg muscular power. The Sargent Jump was not used because of the tremendous skill factor involved in the timing of the arm swing to reach maximum height. In the Modified Vertical Jump, the subject stood sideways to a jump board with his preferred arm extended above his head and next to the board. His other arm was placed behind his back. While standing on tiptoe, the height of his extended fingertips was recorded. Maintaining a straight back and the position of his arms, the subject adopted a full squat position. When stationery and balanced in this position, he sprang upwards and marked the maximum height of his jump on the jump board by means of his chalked fingertips. The jump recorded was the difference between the height of the subject's reach and the maximum height obtained in the jump. All readings were taken to the nearest one quarter of an inch. In the stance feet were shoulder distance apart and parrallel. All subjects were tested while dressed in shorts, t-shirts, and bare feet. Also, to ensure maximum height in the jump, all subjects recieved a series of ten trials to warm up before testing. During the test, each subject was given three consecutive trials with sufficient rest time to rechalk his fingertips and prepare for the next jump. Before each trial, all subjects were instructed to jump as high as possible.

The Standing Broad Jump used in this study, was described by Glencross(7). The subjects were required to dress in shorts, t-shirts and tested in bare feet. Each subject placed his feet as close to the starting line as possible with his feet shoulder distance apart and parallel. Each subject was instructed to assume a comfortable squat position and with a preliminary swing of the arms, to jump as far as possible unto a gymnastics mat. Before the test was administered, a series of practice trials were given to allow the subject to become familiar with the test and to warm up the specific muscles involved in the jump. Before each trial all subjects were instructed to jump as far as possible. To assist in the reading of the distance jumped, white chalk powder was placed on the subject's heels. All subjects were given three trials with readings taken to the nearest quarter of an inch.

The third test of leg muscular power selected was the Ten Yard Sprint with Five Yard Running Start- modified version of Considine and Sullivan(5). Each subject was instructed to stand behind a preliminary line in a staggered position, with his preferred foot ahead. Each subject was dressed in shorts, t-shirt and running shoes. Each subject was told that he would be timed on the last ten yards and that he would have a five yard running start. All were instructed to run as fast as possible. Each subject was given a series of three practice trials to warm up before attempting the test. To make an accurate reading of the time(in seconds)taken to run such a short distance, it was again necessary to adapt the photo-electric system used as the criterion to a system whereby upon hitting the starting line the subject's hip area would break the light beam and start the electronic timer. At the finish, the subject's hip area again broke the light beam and stopped the timer. Each subject had three trials with sufficient time between trials to prepare for the next trial. The electronic timer gave the time it took to cover the ten yards to the nearest five one thousandths of a second. Because it was necessary to administer this test using the photo-electric system, it had to be administered indoors. This necessitated the asking of each subject, after each trial, if he had any slipping problem during any part of the test. All subjects reported that they had no problem. The test used the five yard running start because this study was interested only in the subject's power output and not in the starting skills of the subject.

A fourth conventionally used test of leg muscular power was the Fifty Yard Sprint with Five Yard Running Start. McCloy$_{(12)}$ and Van Dalen$_{(18)}$ reported that the Sprint events were primarily power events. This modified version of several sprint tests was used to overcome differences in starting abilities. All subjects were dressed to meet the standards set in test three. For the five yard running start the subject assumed the same position as he did in the third test. The experimenter stood at the starting line with a stop-watch and started timing as soon as the subject's hip crossed the starting line. The timer was stopped when the subject crossed the finish line as indicated by an assistant who, with the sudden drop of a hand, indicated that the subject had crossed the finish line. Each subject was given three trials and all subjects had sufficient warm-up before being tested. The warm-up consisted of light running for one minute. A five minute rest interval was given between trials to allow the subject to recover.

The fifth and last conventionally used test of leg muscular power, used in this study, was the Bicycle Ergometer Speed Test. This test was described by Gray, Start and Walsh (10). It was used because it not only was found by the above authors that it was a good test of leg speed and correlated significantly with leg power, but because it controlled many of the uncontrolled factors in the sprint tests. There were no variations in length of stride, mechanical efficiency, or running technique as there were in the sprint tests. All subjects recieved a one minute warm-up before the test was administered. This warm-up consisted of pedalling the bicycle ergometer at a one kilogram resistance. Because of variations in height of subjects, the bicycle ergometer seat had to be lowered or raised to make the pedalling of the bicycle ergometer suitable to each subject. Subjects were dressed as specified in tests three and four. A revolution counter was attached to the frame and connected by cams to the wheel. The optimum tension on the resistance hand of the wheel was found by Gray, Start and Walsh (10) to be two and one half kilograms, that is, the minimum resistance to enable the feet to keep firm contact with the pedals and yet not give the feeling of being a strain or endurance effort. The above authors had also found that the optimum duration of the test ride had to be sufficient to allow the initial inertia of the bicycle ergometer to be overcome and full speed to be reached and maintained for a short period. The test ride also had to be short enough in duration not to introduce any endurance factor. They found that the ten-second test produced the highest average rate of revolutions per second. In this study, the subjects were instructed not to lose contact with the seat throughout the duration of the test. The ten-second interval was measured by a stop watch which indicated when to start and stop the revolution counter. All subjects were given three trials with a five minute rest interval between trials.

In each of the tests used in this study, each subject was given three attempts. However, in the statistical treatment of the data, the best attempt in each test was used.

Treatment of data:

Five Pearson Product Moment Correlation Coefficients were used to correlate each of the five conventional tests of leg muscular power with the criterion measure of leg power to determine if the conventionally used tests were valid measures of the maximum power output. Five other Pearson Product Moment Correlation Coefficients were used to correlate each of the five conventional tests to power per pound body weight to determine if the five conventional tests were valid measures of power per pound body weight.

CHAPTER IV

RESULTS-DISCUSSION

TABLE II

THE PEARSON PRODUCT MOMENT CORRELATION COEFFICIENTS FOR THE RELATIONSHIP OF THE FIVE CONVENTIONAL TESTS OF LEG MUSCULAR POWER TO THE TOTAL POWER OUTPUT AS DETERMINED BY THE CRITERION MEASURE

CONVENTIONAL TESTS	CORRELATION COEFFICIENTS
Modified Vertical Jump	.11
Standing Broad Jump	.11
Ten Yard Sprint with Five Yard Running Start	- .01
Fifty Yard Sprint with Five Yard Running Start	- .18
Bicycle Ergonometer Speed Test	.07

TABLE III

THE PEARSON PRODUCT MOMENT CORRELATION COEFFICIENTS FOR THE RELATIONSHIP OF THE FIVE CONVENTIONAL TESTS OF LEG MUSCULAR POWER TO POWER PER POUND BODY WEIGHT AS DETERMINED BY THE CRITERION MEASURE

CONVENTIONAL TESTS	CORRELATION COEFFICIENTS
Modified Vertical Jump	.36
Standing Broad Jump	.34
Ten Yard Sprint with Five Yard Running Start	-.07
Fifty Yard Sprint with Five Yard Running Start	-.21
Bicycle Ergonometer Speed Test	.14

TABLE IV

MAXIMUM POWER OBTAINED AT
GIVEN PERCENTAGES OF
MAXIMUM LIFT

KEY A - PERCENTAGE OF MAXIMUM LIFT
B - PERCENTAGE OF MAXIMUM POWER OBTAINED

SUBJECT	KEY	PERCENTAGES				
1	A	21.05	31.58	42.11	52.63	57.89
	B	70.91	79.09	89.23	100.00	89.38
2	A	21.05	31.58	42.11	52.63	57.89
	B	72.50	87.00	100.00	96.67	92.73
3	A	20.00	30.00	40.00	50.00	60.00
	B	76.36	84.00	94.65	100.00	85.42
4	A	18.18	31.82	40.91	50.00	59.09
	B	67.23	84.98	100.00	94.88	92.63
5	A	20.00	30.00	40.00	50.00	60.00
	B	59.57	83.57	87.50	100.00	95.55
6	A	21.74	30.43	39.13	52.17	60.87
	B	87.47	89.93	100.00	99.66	88.55
7	A	18.18	31.82	40.91	50.00	59.09
	B	66.67	84.25	88.64	100.00	92.35
8	A	20.00	33.33	40.00	53.33	60.00
	B	81.25	96.73	100.00	99.62	94.66
9	A	19.05	28.57	38.10	52.38	61.90
	B	56.42	74.05	81.71	100.00	77.02
10	A	21.05	31.58	42.11	52.63	57.89
	B	63.64	84.98	100.00	94.88	92.63
11	A	21.05	31.58	42.11	52.53	57.89
	B	76.30	83.93	9[illegible].92	100.00	88.77
12	A	17.65	29.41	41.18	52.94	70.59
	B	59.52	83.33	91.15	100.00	84.75
13	A	18.75	31.25	35.50	50.00	62.50
	B	66.35	84.56	94.52	100.00	91.27

TABLE IV cont...

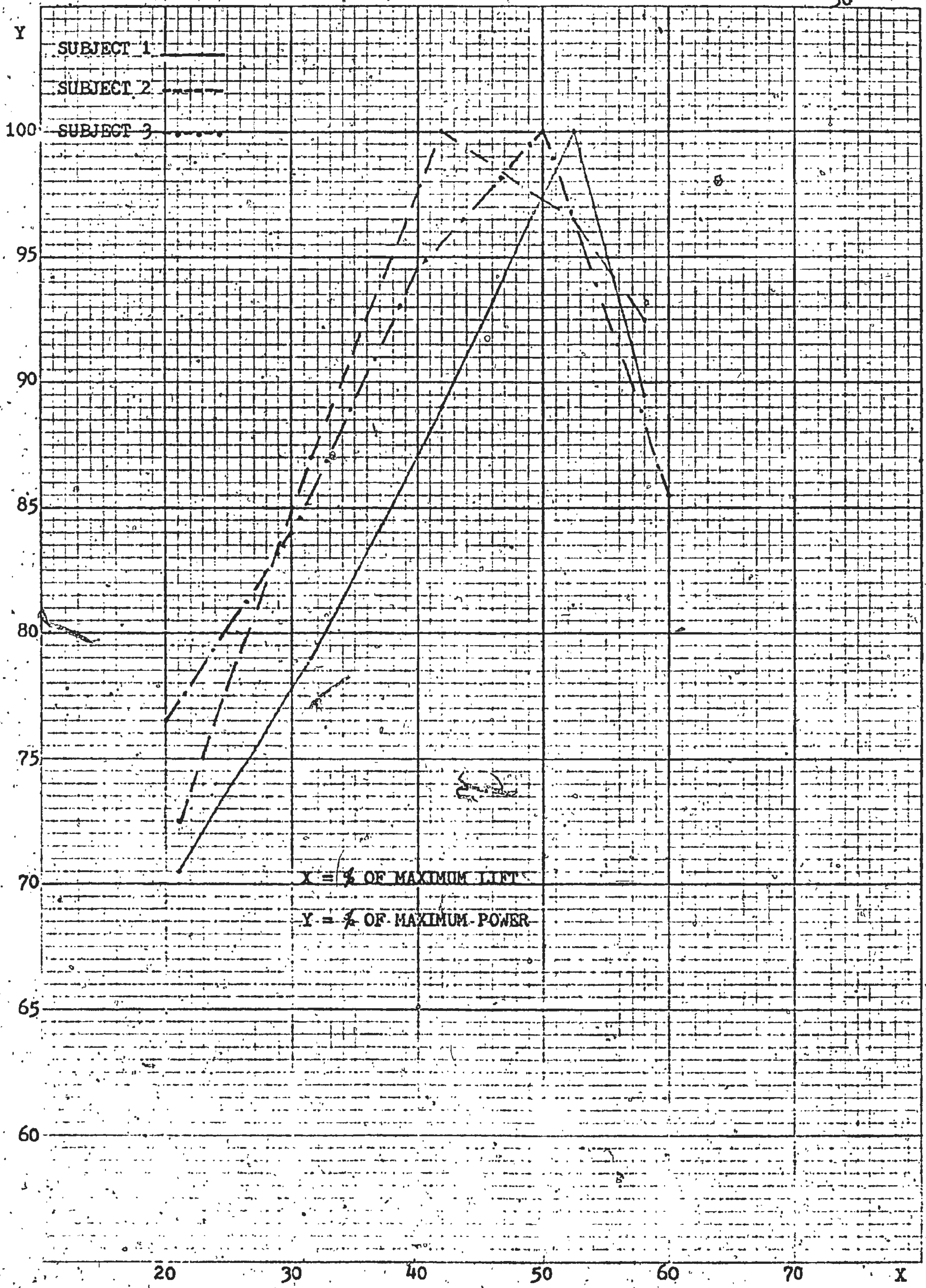
KEY A - PERCENTAGE OF MAXIMUM LIFT
B - PERCENTAGE OF MAXIMUM POWER OBTAINED

SUBJECT	KEY	PERCENTAGES				
14	A	21.05	31.58	42.11	52.63	57.89
	B	72.62	84.72	100.00	95.31	93.19
15	A	20.00	30.00	40.00	50.00	60.00
	B	64.44	83.65	100.00	92.95	92.55
16	A	20.59	29.41	41.18	50.00	58.82
	B	74.93	84.80	87.90	100.00	54.41
17	A	20.00	32.00	40.00	52.00	60.00
	B	68.89	85.52	100.00	95.95	93.00
18	A	19.05	28.57	38.10	52.38	61.90
	B	64.39	77.27	90.91	100.00	88.12
19	A	19.35	29.03	38.71	51.61	61.29
	B	83.33	100.00	67.71	64.92	47.32
20	A	20.00	32.00	40.00	52.00	60.00
	B	84.21	100.00	91.43	90.43	84.21
21	A	19.05	33.33	42.86	52.38	61.90
	B	72.73	86.15	94.74	100.00	96.30
22	A	20.00	30.00	40.00	50.00	60.00
	B	69.05	80.56	100.00	97.97	94.57
23	A	18.18	31.82	40.91	50.00	59.09
	B	60.61	82.49	84.23	100.00	81.11
24	A	20.00	30.00	40.00	50.00	60.00
	B	70.45	93.00	100.00	94.51	77.50
25	A	20.00	32.00	40.00	52.00	60.00
	B	73.68	93.33	100.00	91.00	85.71
26	A	19.05	33.33	42.86	52.38	61.90
	B	77.69	80.83	83.60	100.00	75.06
27	A	18.18	31.82	40.91	50.00	59.09
	B	60.60	84.85	88.45	100.00	89.19

TABLE IV cont...

KEY A - PERCENTAGE OF MAXIMUM LIFT
B - PERCENTAGE OF MAXIMUM POWER OBTAINED

SUBJECT	KEY	PERCENTAGES				
28	A	19.05	33.33	42.86	52.38	61.90
	B	64.44	80.55	100.00	95.79	82.13
29	A	21.05	31.58	42.11	52.63	57.89
	B	76.09	97.22	100.00	97.22	94.36
30	A	19.44	30.56	38.89	50.00	61.00
	B	85.58	100.00	91.92	65.79	63.41
31	A	19.05	28.57	38.10	52.38	61.90
	B	61.54	85.71	96.97	100.00	99.05
32	A	18.18	31.82	40.91	50.00	59.09
	B	66.43	94.46	94.79	100.00	90.54
33	A	19.05	28.57	38.10	52.38	61.90
	B	62.50	81.25	100.00	93.09	92.65
34	A	1765	29.41	41.18	52.94	70.59
	B	57.69	86.21	100.00	95.74	92.31
35	A	20.00	32.00	40.00	52.00	60.00
	B	68.59	78.39	79.14	100.00	82.31
36	A	17.65	29.41	41.18	52.94	70.59
	B	68.42	83.33	84.26	100.00	97.20
37	A	22.22	27.78	38.89	50.00	61.11
	B	70.13	74.18	100.00	89.01	83.19
38	A	20.00	32.00	40.00	52.00	60.00
	B	77.78	94.65	100.00	79.33	78.15
39	A	21.74	30.43	39.13	52.17	60.87
	B	68.38	88.89	100.00	98.08	36.07
40	A	20.83	29.17	41.67	50.00	58.33
	B	79.54	89.09	97.22	100.00	85.22
41	A	18.18	31.82	40.91	50.00	59.09
	B	68.69	96.16	100.00	92.35	90.95
42	A	19.05	28.57	38.10	52.38	61.90
	B	63.64	81.82	95.45	100.00	82.73



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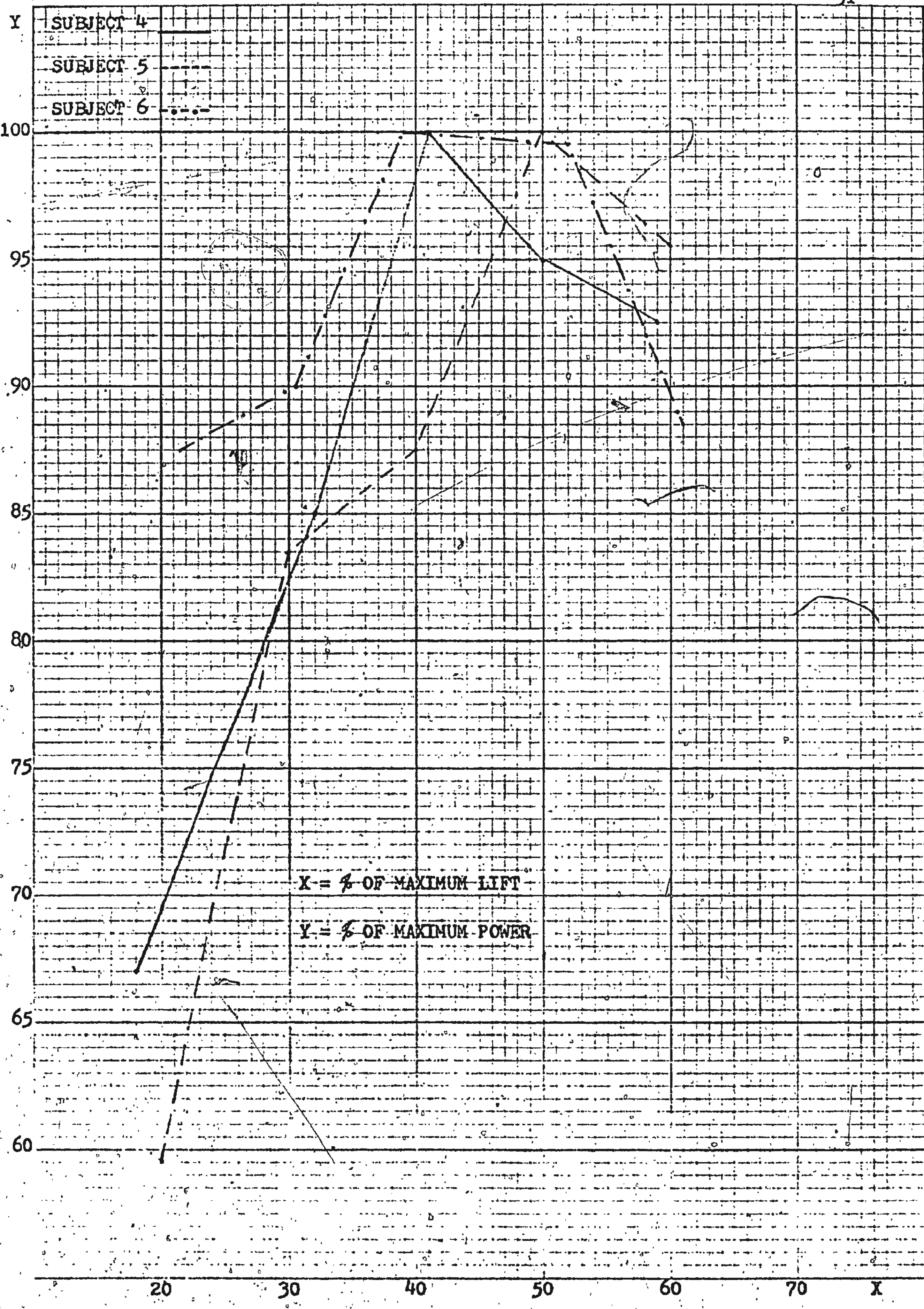
Y = % OF MAXIMUM POWER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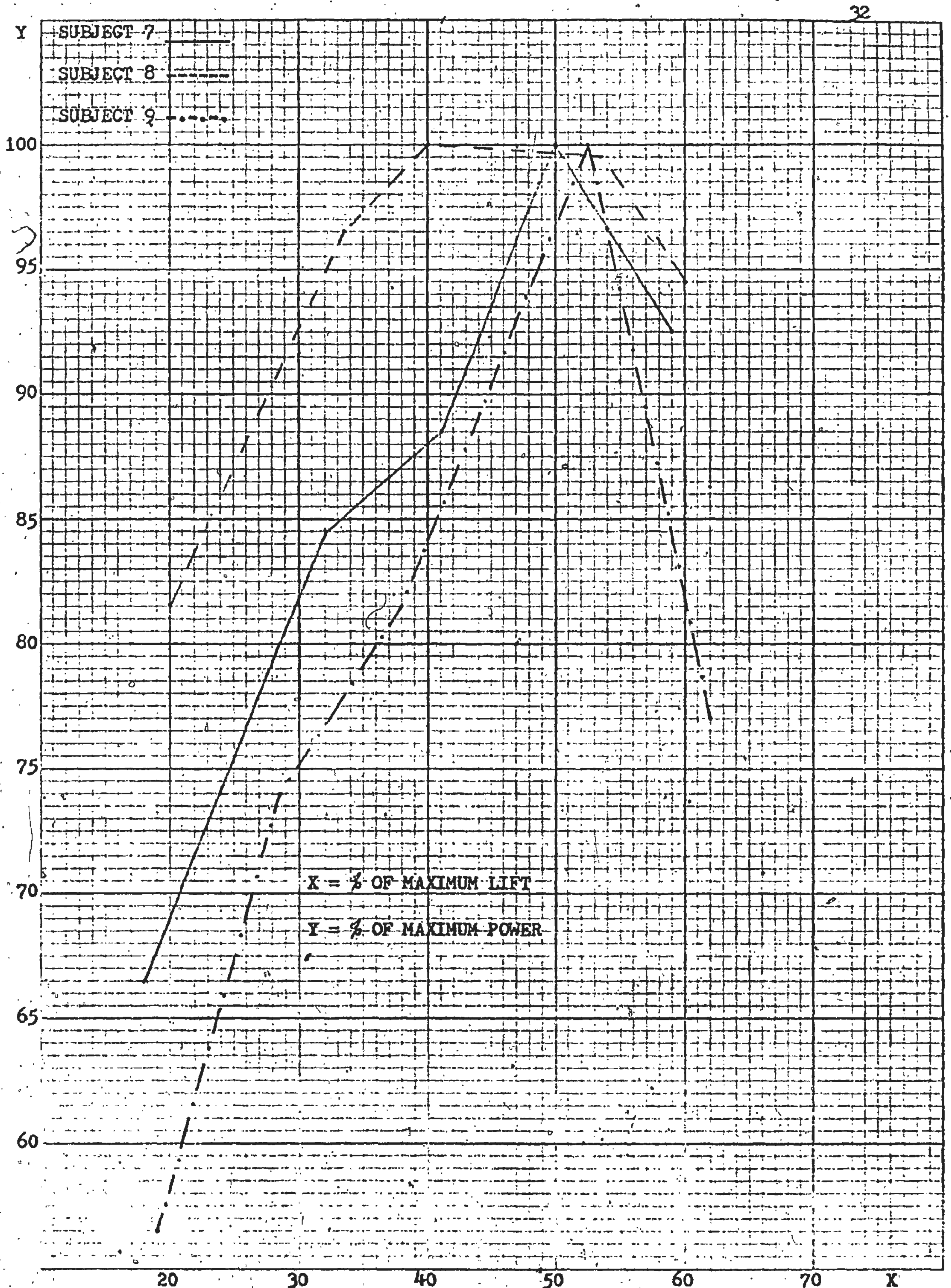
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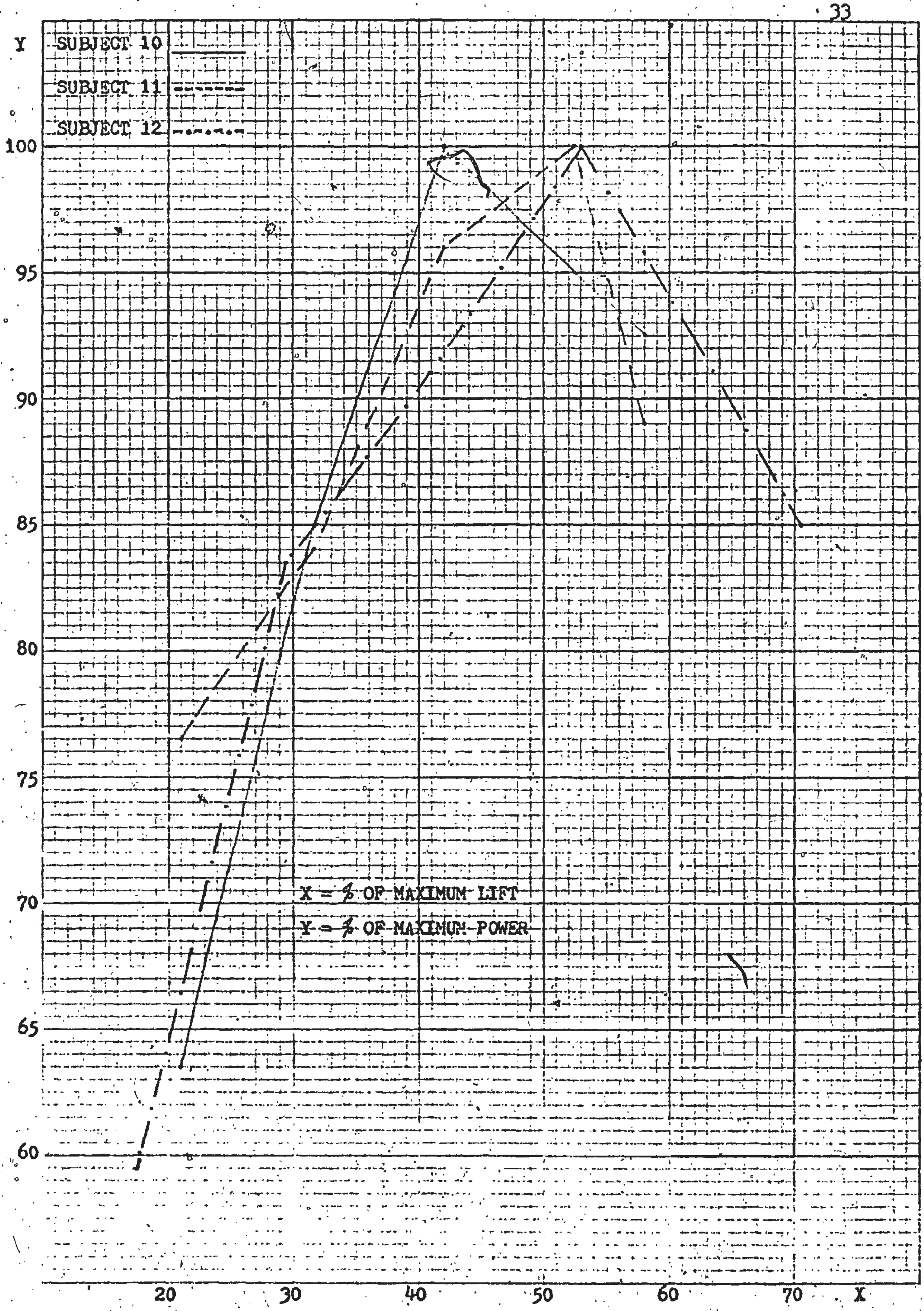
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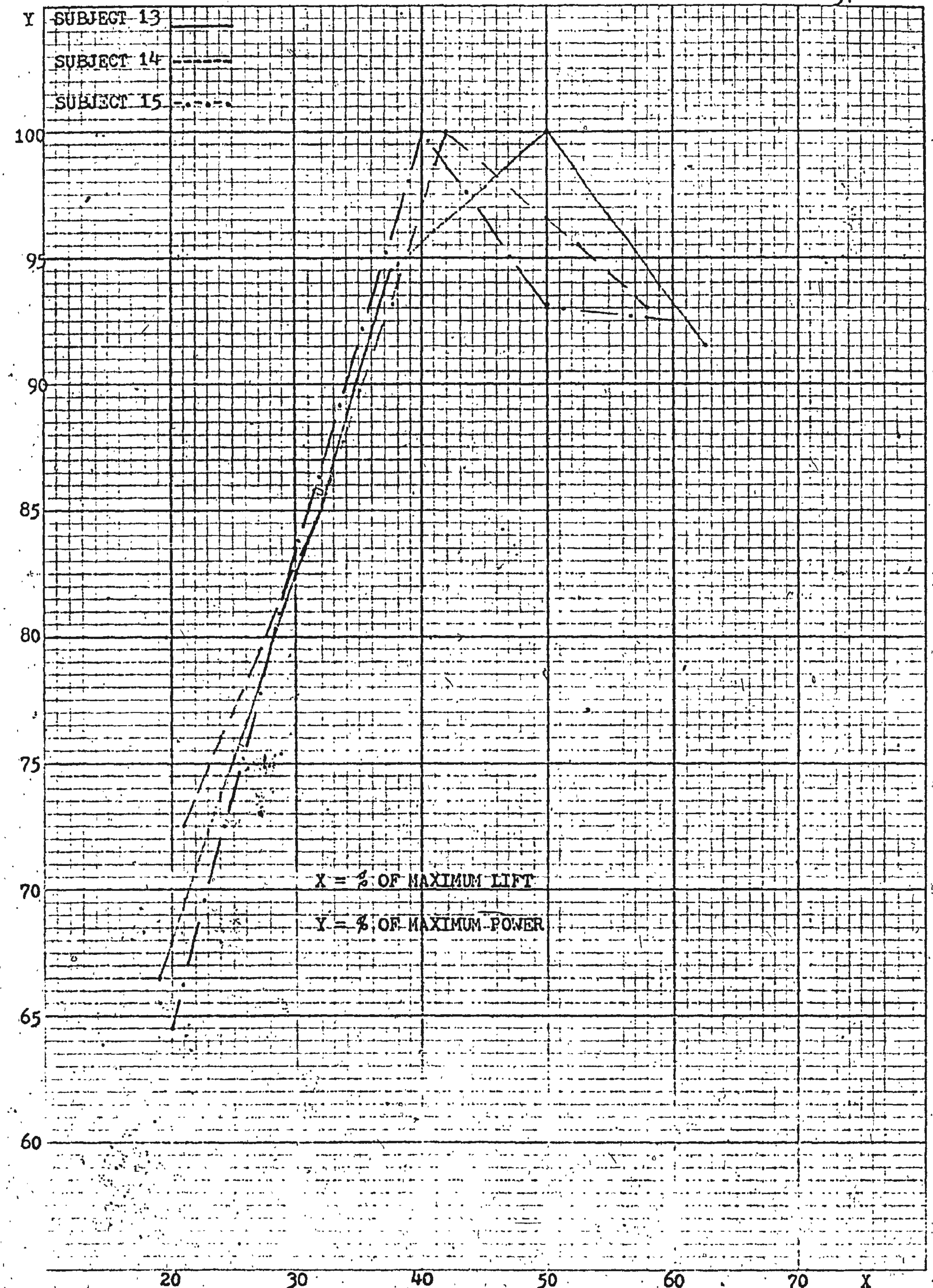

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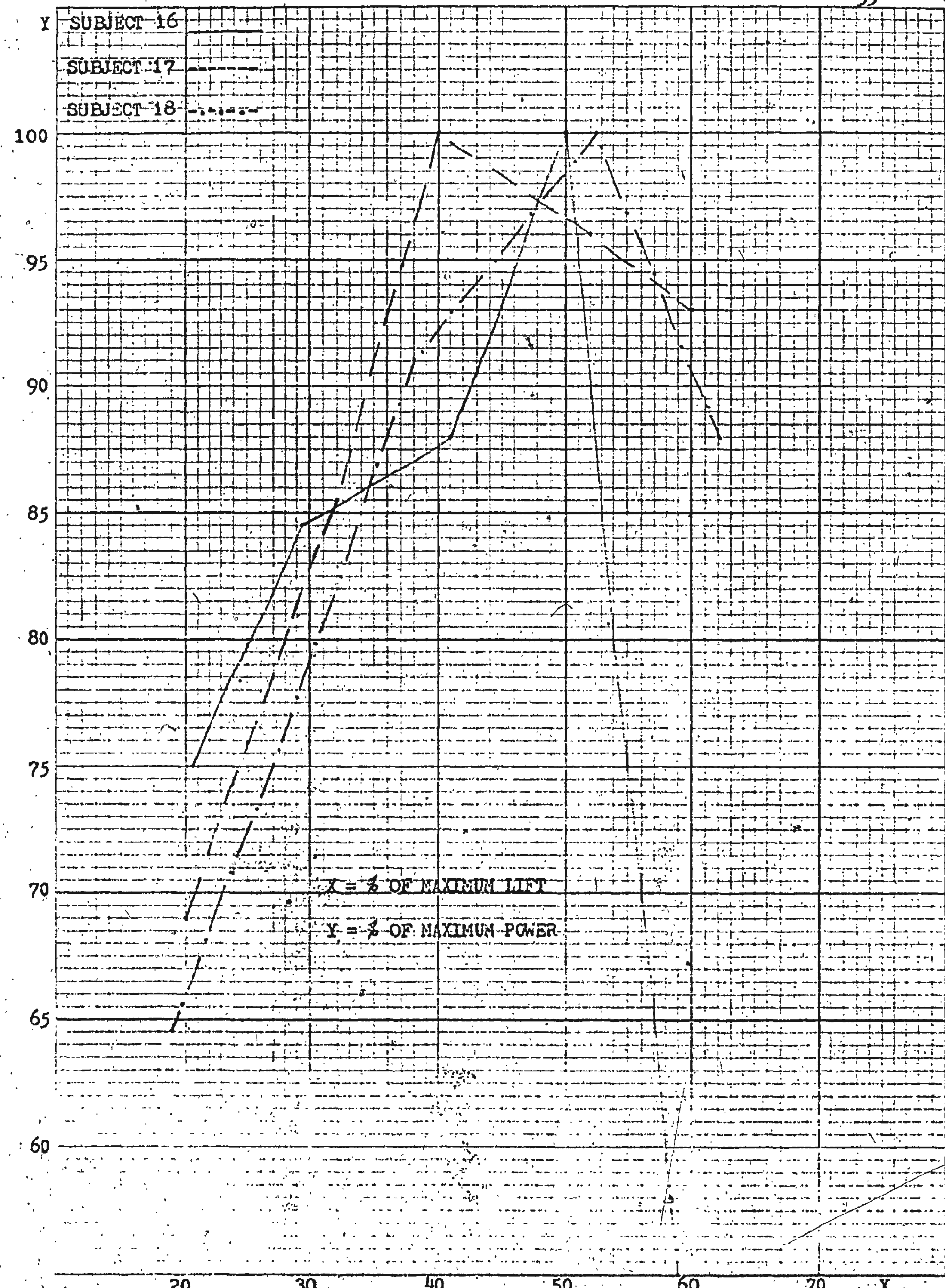
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Y = % OF MAXIMUM POWER
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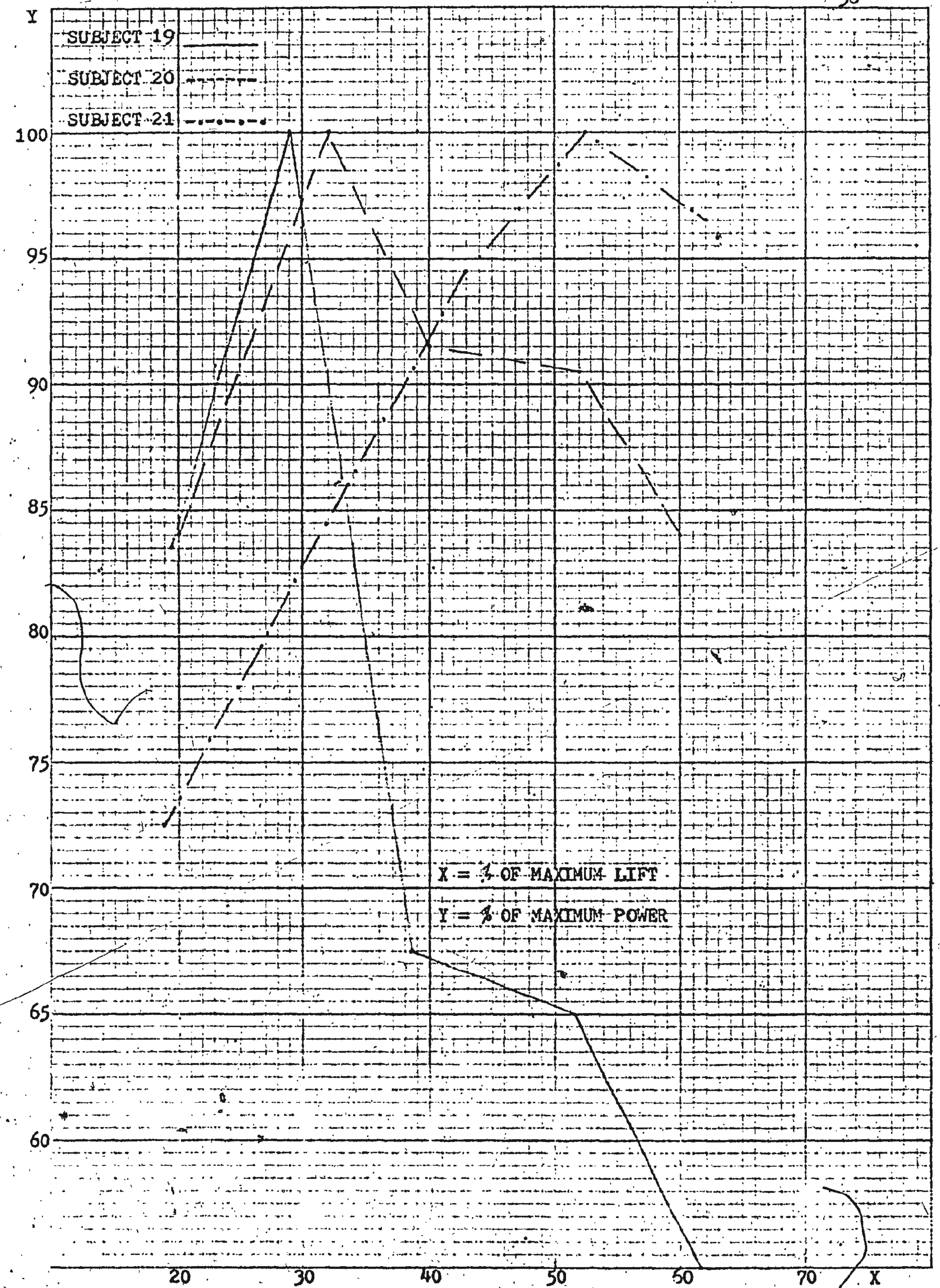
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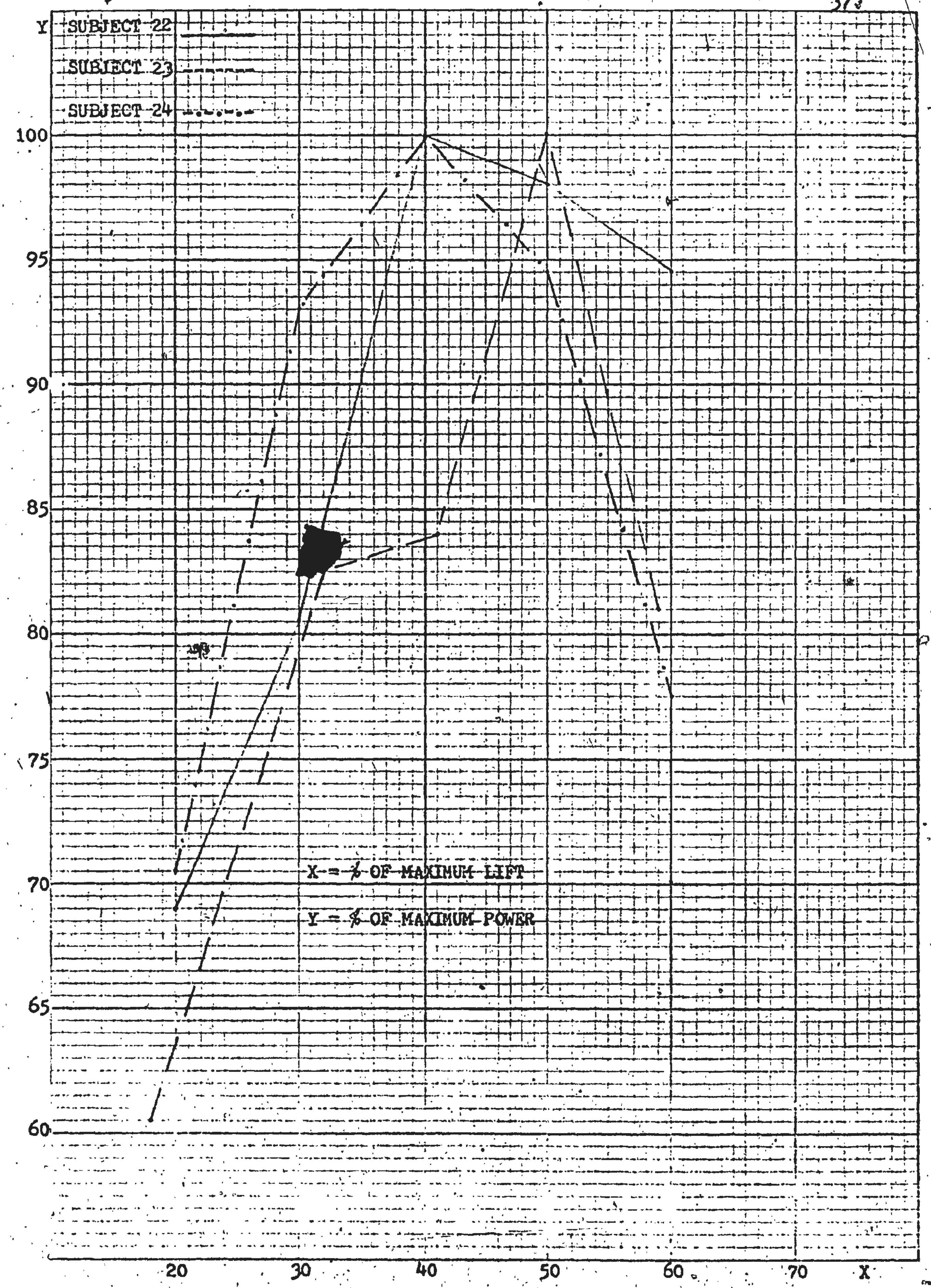

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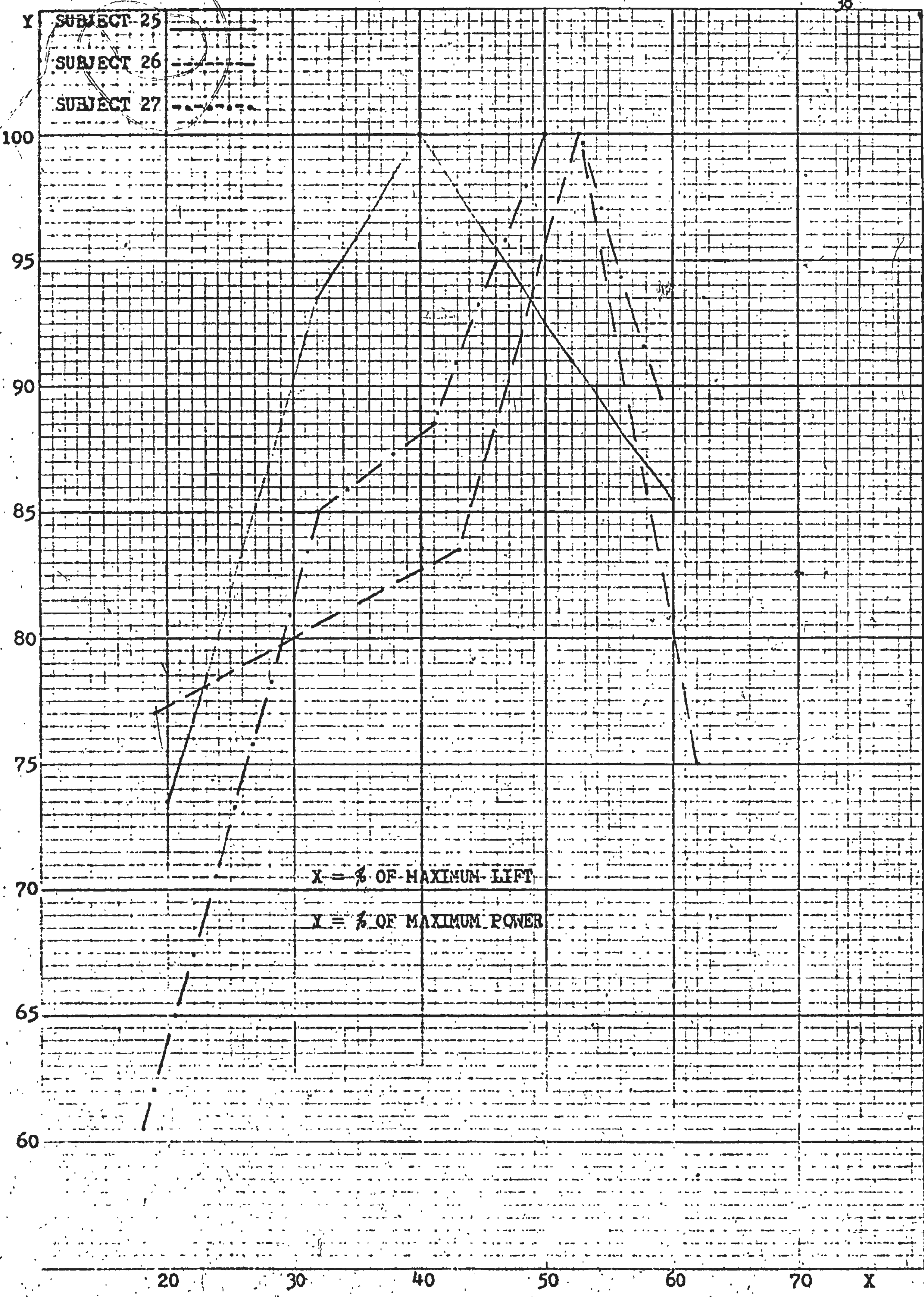
Y = % OF MAXIMUM POWER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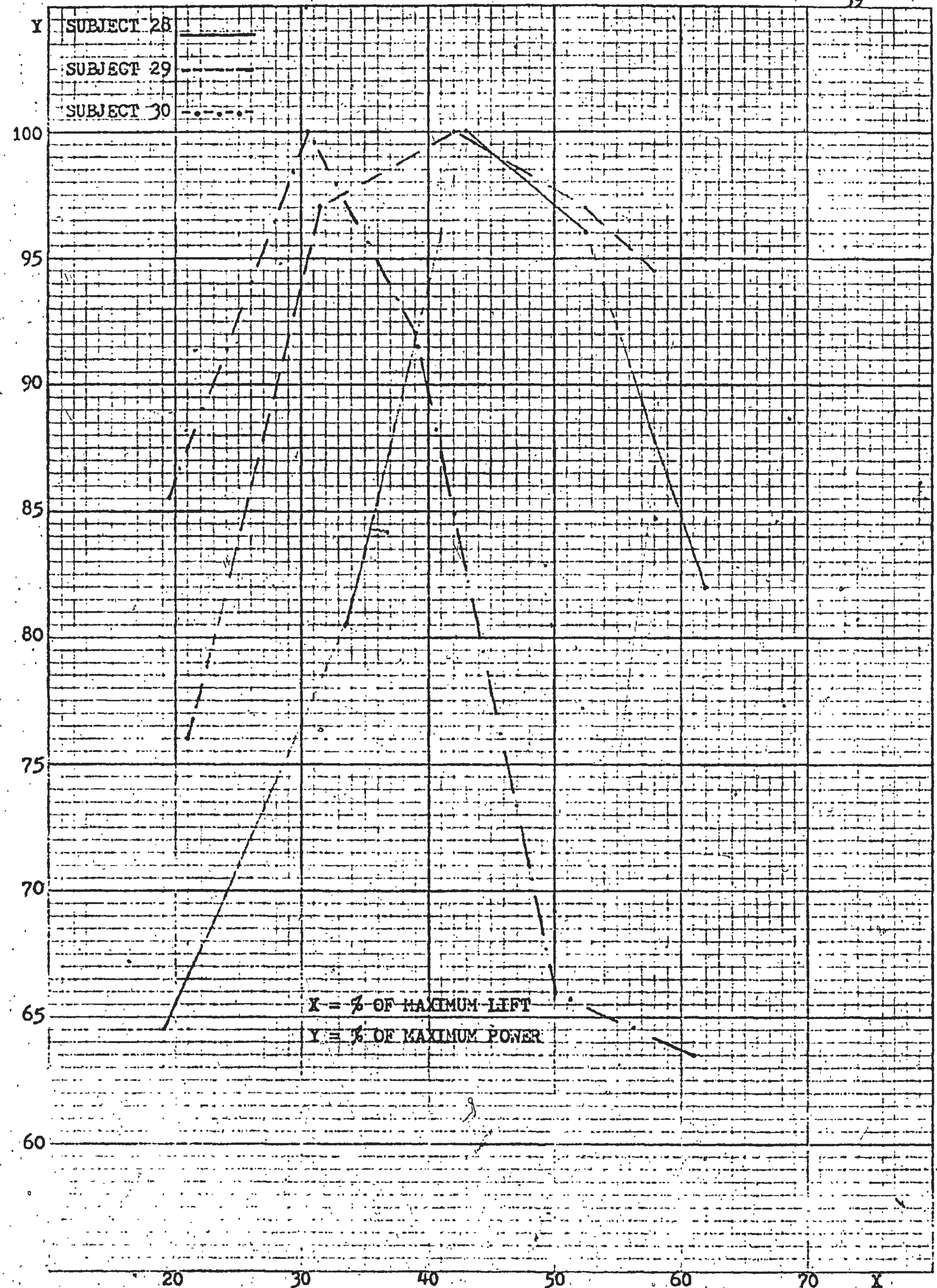
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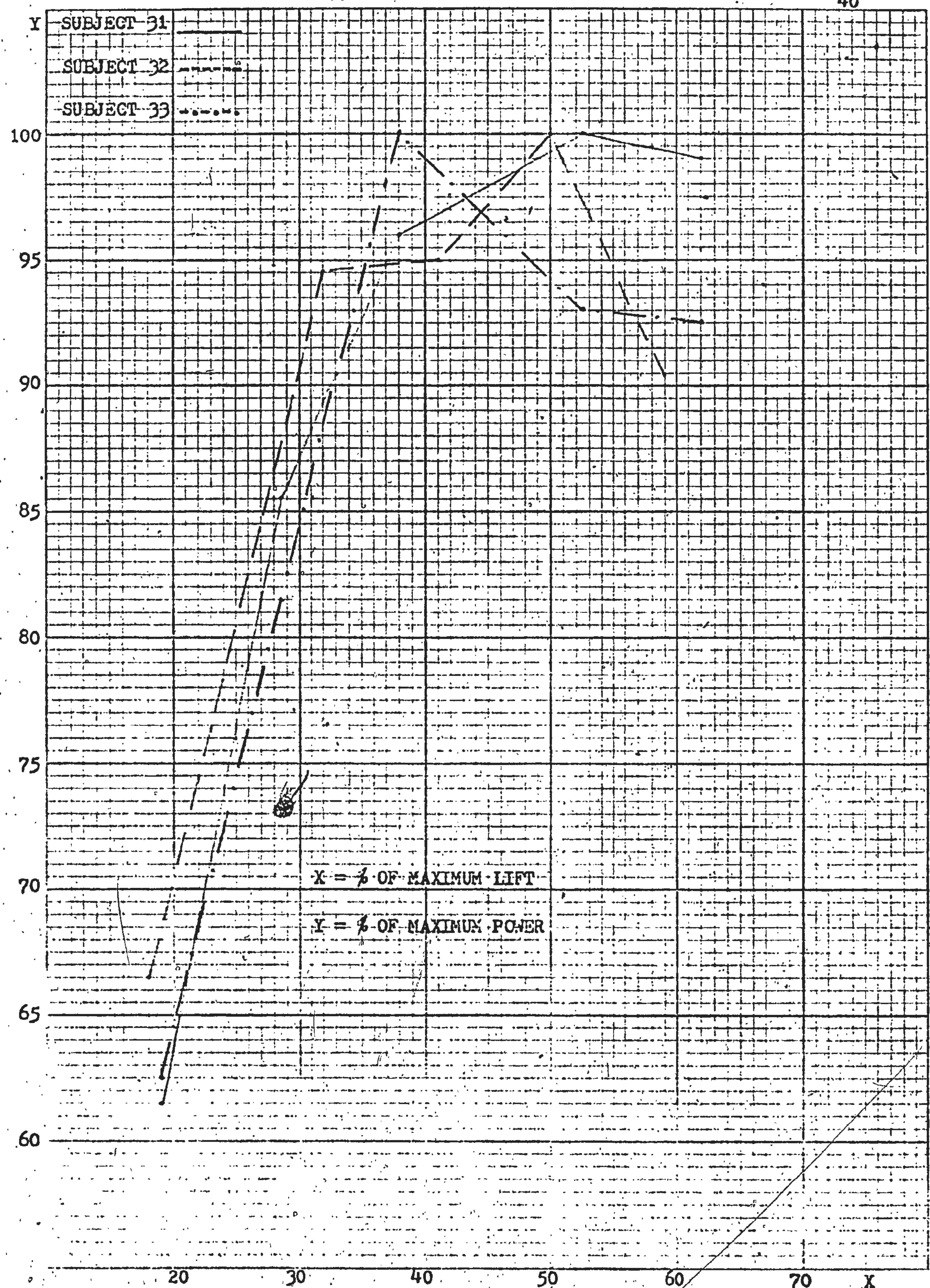
Y = % OF MAXIMUM POWER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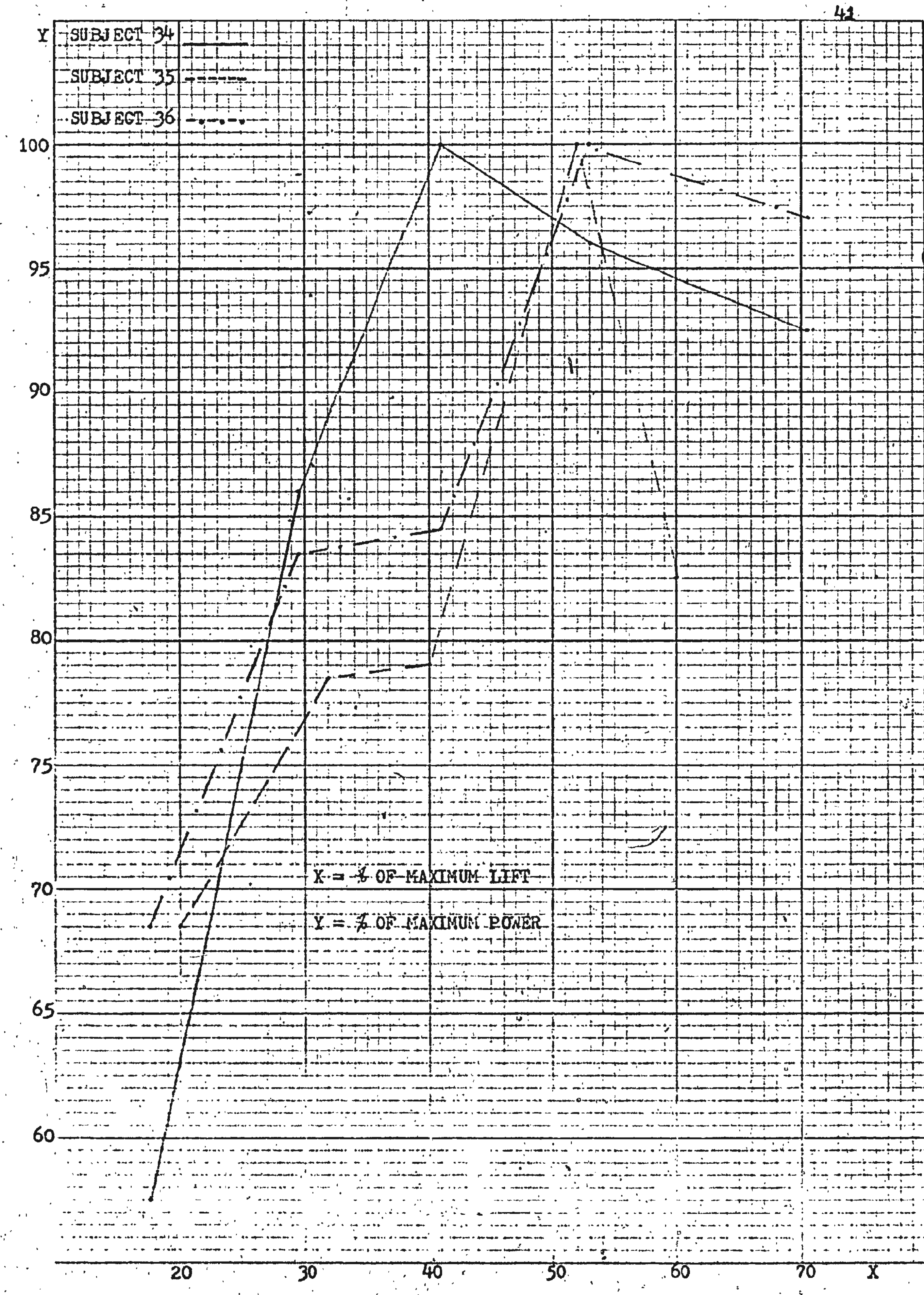
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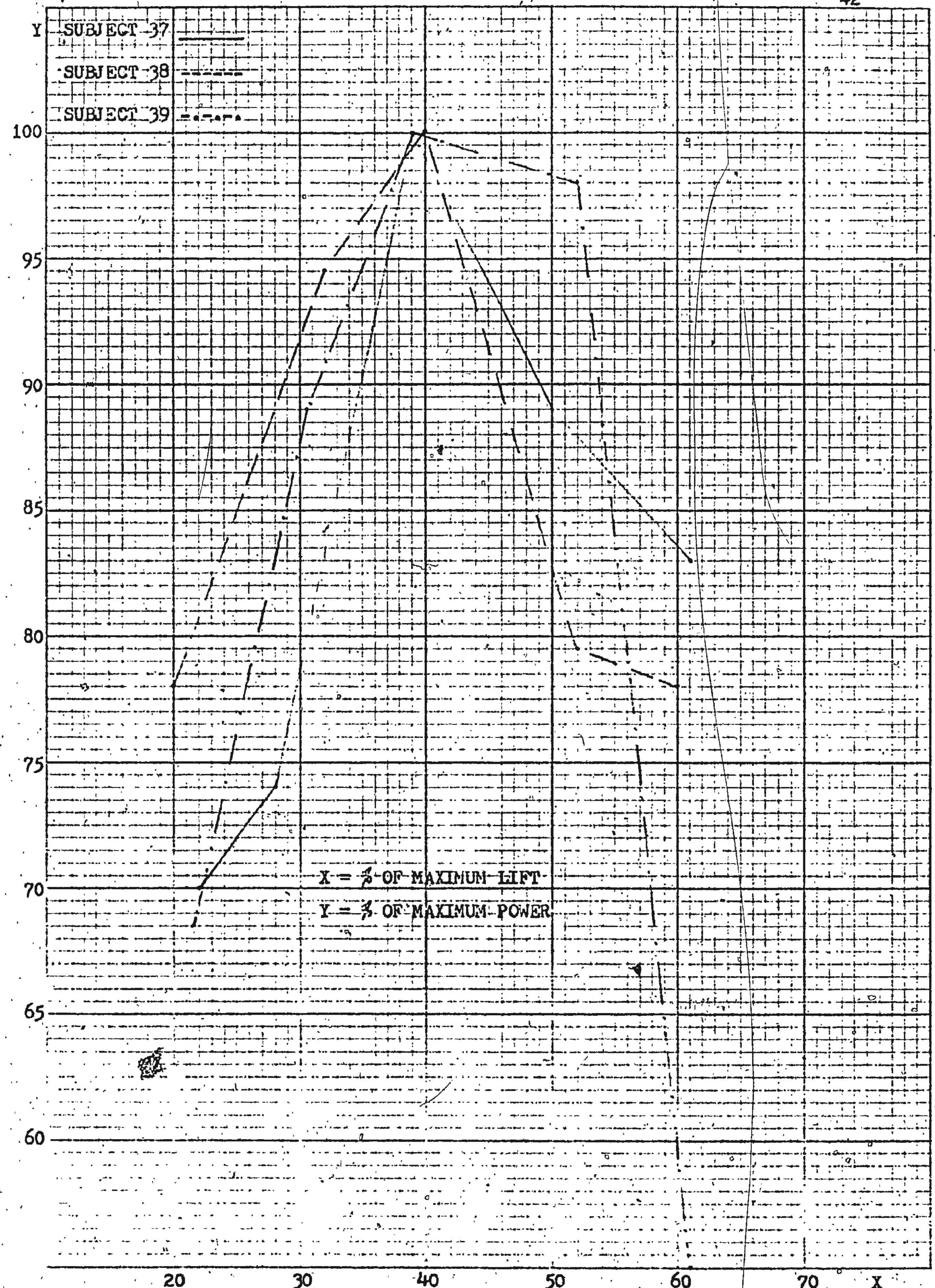
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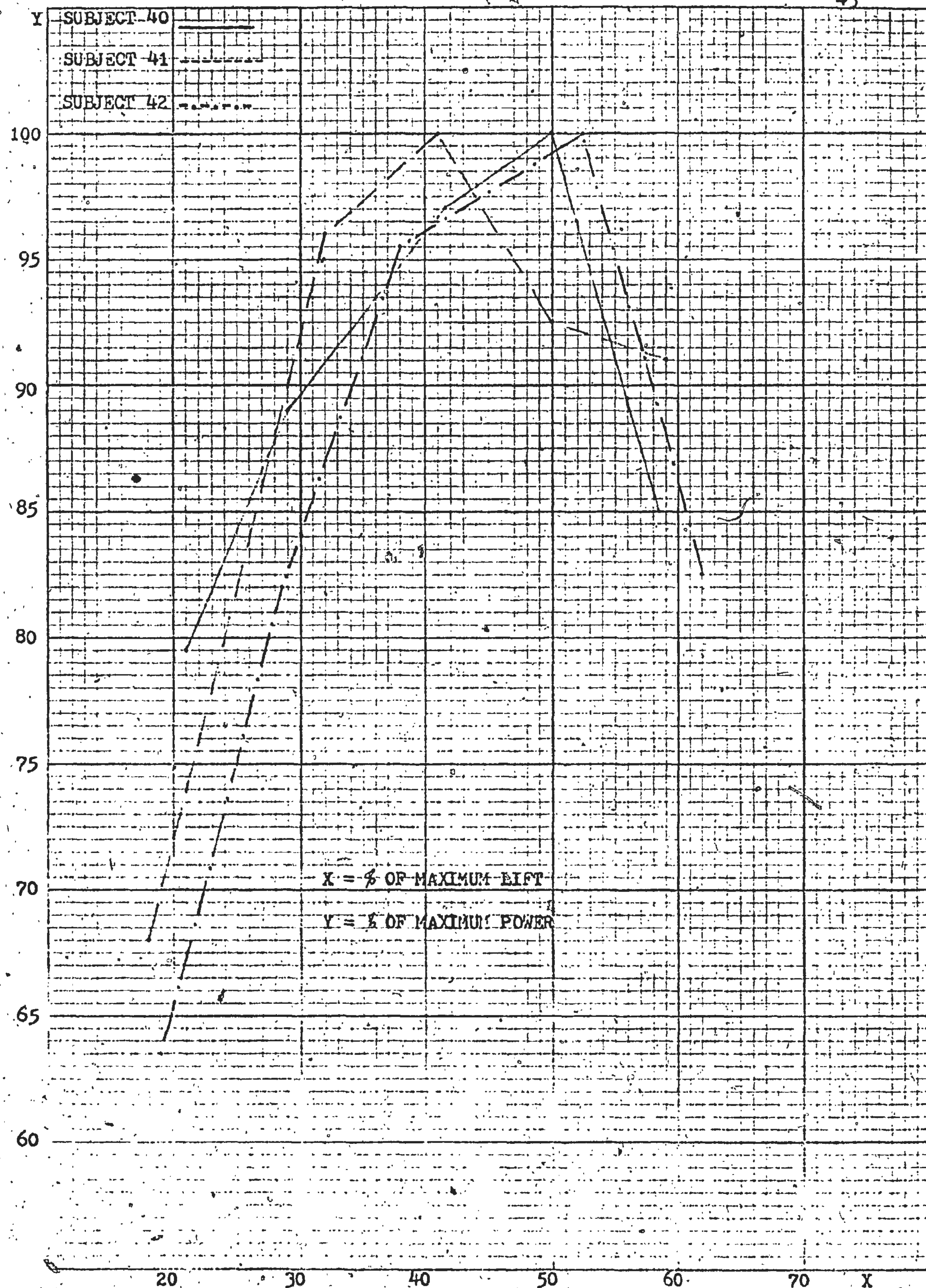

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X = % OF MAXIMUM LIFT
Y = % OF MAXIMUM POWER

As indicated in Table II, neither of the conventionally used tests of leg muscular power correlated significantly with the true measure of maximum leg power. The Pearson Product Moment Correlation Coefficients for the Modified Vertical Jump, Standing Broad Jump, Ten Yard Sprint with Five Yard Running Start, Fifty Yard Sprint with Five Yard Running Start and the Bicycle Ergometer Speed Test to the true measure of maximum leg power were .11, .11, -.01, -.18, and .07, respectively. All values were insignificant at the .01 level.

Table III has indicated that the five conventionally used tests of leg power correlated significantly higher when compared to the criterion value expressed in power per pound body weight. The Pearson Product Moment Correlation Coefficients for each of the conventional tests when compared to power per pound body weight were: Modified Vertical Jump .36, Standing Broad Jump .34, Ten Yard Sprint with Five Yard Running Start -.07, Fifty Yard Sprint with Five Yard Running Start -.21, and Bicycle Ergometer Speed Test .14. However, all five correlations were still insignificant at the .01 level.

As indicated in table IV, the optimum load for maximum power output ranged from 29 percent to 53 percent. The average optimum was calculated to be 45 percent.

Discussions:

The values of the correlations between the true measure of leg muscular power and each of the five conventionally used tests of leg power as measured in this study were insignificant at the .01 level. However, it was noted that the conventional tests were better indicators of power per pound body weight, than they were of the maximum power output.

The findings of this study were supported by the past research which utilized the physical sciences' definition of power as the criterion measure(1,4,6,7). However, the correlation coefficients obtained in this study have indicated that the relationship of the conventional tests of leg power to the true measure was even lower than the previously established values. With respect to other studies(8,9,12,18), the results of this study would disagree with their findings. The explanation of this disagreement took into consideration the fact that the above researchers validated tests of leg power because of their relationship to an unjustified criterion measure. Also, these supposedly validated tests were developed without consideration of the time factor, that is, not obeying the physical sciences' definition of power. In the studies which did consider the time factor(1,4,6,8), only one load was experimented with to determine the power output. It was not determined if this one load yielded the maximum power output. If the conventional tests were valid measures of the ability of the body to develop power, then they should correlate significantly with the total maximum power output. If, however, this was dependent on the weight that had to be moved or in this case, the subject's weight, then the conventional tests should correlate significantly with power per pound body weight. In both instances, this was not the case and it was therefore assumed that the conventional tests of leg power were not valid measures.

CHAPTER V

SUMMARY-CONCLUSIONS

The purpose of this study was to determine the validity of the conventional tests of leg muscular power, namely, (1) Modified Vertical Jump, (2) Standing Broad Jump, (3) Ten Yard Sprint with Five Yard Running Start, (4) Fifty Yard Sprint with Five Yard Running Start, and (5) Bicycle Ergometer Speed Test. Many previous studies have tested the validity of these tests, but all have failed because of their inability to devise a true criterion measure of leg power.

The sample (N = 42) was chosen from second and third year male physical education students at Memorial University of Newfoundland on the basis of their availability. Each subject was required to undergo (1) each of the conventional tests of leg power, and (2) the criterion measure of leg power which was based upon the physical sciences' definition of power and employed a photo-electric system.

The statisical analsis employed in this study was the Pearson Product Moment Correlation which enabled the researcher to determine (1) the relationship of each of the conventional tests of leg power to the total maximum leg power output as given by the criterion measure and (2) the relationship of each of the conventional tests of leg power to the power per pound body weight as given by the criterion measure divided by the subject's weight. In all cases the Pearson Product Moment Correlation Coefficients were insignificant at the .01 level. Therefore, none of the conventional tests of leg power correlated significantly with the criterion measure. It was also found that the average optimum load which yielded the maximum power output was equal to 45 percent of the subject's maximum lift.

The results obtained led to the following conclusions:

(1) The conventional tests of leg muscular power, as used in this study - namely, (i) Modified Vertical Jump, (ii) Standing Broad Jump, (iii) Ten Yard Sprint with Five Yard Running Start, (iv) Fifty Yard Sprint with Five Yard Running Start, (v) Bicycle Ergonometer Speed Test, were not valid measures of the total maximum power output.

(2) The conventional tests of the muscular power as used in this study were not valid measures of the power per pound body weight output.

(3) The optimum load for maximum leg power output ranged from 29 percent to 53 percent, with an average of 45 percent.

Recommendations:

Within the limitations of this study, the conclusions arrived at were considered valid. However, there were a number of areas which needed much more emphasis before any more practical implications can be made. For example, how will the optimum power output change with training? Similarily, how will the components of power change, that is, how will force and velocity change with training? To answer these questions, much more research must be done with consideration of pre and post power output divided by a prolonged period of well controlled training periods.

From a performance point of view, D. J. Glencross has stated that there is need to determine the optimum load for maximum power development. This load must be expressed as a percentage of the maximum strength of the muscle groups involved. Therefore, assuming that the track(sprints) and field events to be primarily power events, this knowledge would greatly enhance the training of athletes. If, however, training does change the optimum load at which maximum power output is achieved, the athlete's optimum load must be calculated, not only before training, but periodically during training to assure that he is always training at the load which will produce maximum power development.

It was found in this study that the optimum load or the percentage of maximum lift which yielded the greatest power output ranged from 29 percent to 53 percent with an average of 45 percent. The large range may be accounted for by the fact that the forty-two subjects used ranged from relatively low activity individuals to varsity athletes. Therefore, in any further study concerned with finding the optimum load, a more careful selection of subjects is recommended. In addition, the variety of weights used also had drawbacks in the fact that not only were the weights in the Imperial measure, but, they were given in twenty pound increments. Therefore, any further study should concentrate on the Metric system and most importantly, use smaller increments of weight. However, in doing so, the researcher must be wary of the possible fatigue factor in too many repetitions.

In any case, if further research is done on power, it seems obvious that consideration must be given to power as defined by the physical sciences. As it stands, there is still need to devise a simplified but valid indicator of leg muscular power.

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APPENDICES

APPENDIX A

TABLE V

PHYSICAL CHARACTERISTICS OF SUBJECTS

SUBJECT	AGE(YRS.)	WEIGHT(LBS.)
1	21.0	210.50
2	20.5	138.50
3	20.0	140.50
4	20.5	136.50
5	22.0	156.00
6	19.0	174.75
7	20.0	156.25
8	21.5	139.50
9	20.0	159.00
10	19.5	149.50
11	22.0	153.75
12	19.5	160.75
13	18.0	142.50
14	20.5	135.00
15	18.5	189.00
16	19.0	170.00
17	22.5	169.50
18	23.5	158.00
19	19.5	140.00
20	20.0	180.00
21	22.0	175.25
22	20.0	165.00
23	24.0	174.75
24	20.5	134.75
25	24.0	173.50
26	19.5	167.25
27	22.5	171.25
28	19.5	178.25
29	20.0	127.50
30	21.0	154.75
31	20.5	179.25
32	21.5	158.50
33	21.5	134.75
34	24.0	129.00
35	23.5	176.25
36	22.0	146.00
37	22.5	151.25
38	19.0	139.25
39	19.0	167.50
40	20.0	152.25
41	21.5	156.25
42	19.5	175.25

TABLE VI

TIME OF MOVEMENT AT THE GIVEN PERCENTAGE OF MAXIMUM LIFT

SUBJECT	MAXIMUM LIFT (LBS.)	20%	30%	40%	50%	60%
1	380	80	120	160	200	220
		.220	.410	.325	.470	.480
		.220	.280	.325	.450	.490
		.220	.275	.340	.390	.500
2	380	80	120	160	200	220
		.200	.275	.300	.375	.430
		.210	.340	.290	.390	.465
		.210	.250	.305	.420	.440
3	400	80	120	160	200	240
		.235	.320	.370	.475	.525
		.220	.315	.355	.440	.620
		.225	.300	.370	.420	.420
4	440	80	140	180	220	260
		.200	.270	.295	.390	.460
		.240	.290	.320	.400	.460
		.195	.300	.320	.380	.480
5	400	80	120	160	200	240
		.270	.290	.320	.400	.500
		.270	.280	.325	.390	.490
		.280	.290	.330	.395	.495
6	460	100	140	180	240	280
		.240	.320	.370	.495	.650
		.235	.320	.375	.540	.675
		.240	.340	.390	.510	.740
7	440	80	140	180	220	260
		.260	.390	.440	.490	.610
		.290	.370	.450	.540	.630
		.270	.360	.460	.475	.640
8	300	60	100	120	160	180
		.215	.300	.350	.450	.515
		.215	.280	.340	.450	.525
		.200	.295	.325	.435	.635
9	420	80	120	160	220	260
		.220	.255	.290	.420	.500
		.225	.240	.305	.340	.550
		.210	.240	.355	.325	.590
10	380	80	120	160	200	220
		.240	.310	.325	.350	.575
		.230	.310	.370	.500	.610
		.220	.300	.380	.490	.575

TABLE VI cont...

SUBJECT	MAXIMUM LIFT (LBS.)	20%	30%	40%	50%	60%
11	380	80	120	160	200	220
		.210	.290	.350	.420	.520
		.240	.310	.400	.450	.520
		.220	.320	.370	.460	.530
12	340	60	100	140	180	240
		.210	.260	.320	.375	.590
		.230	.250	.330	.390	.660
		.210	.250	.340	.385	.610
13	320	60	100	120	160	200
		.330	.340	.410	.475	.630
		.260	.380	.365	.460	.640
		.280	.370	.390	.470	.640
14	380	80	120	160	200	220
		.240	.270	.305	.405	.470
		.230	.270	.330	.410	.450
		.210	.280	.310	.400	.460
15	400	80	120	160	200	240
		.225	.290	.300	.390	.480
		.230	.270	.310	.400	.470
		.225	.260	.290	.390	.470
16	680	140	200	280	340	400
		.310	.385	.570	.760	1.600
		.305	.390	.520	.555	1.200
		.320	.400	.550	.590	1.300
17	500	100	160	200	260	300
		.290	.290	.310	.440	.500
		.225	.300	.330	.420	.530
		.240	.310	.320	.430	.510
18	420	80	120	160	200	260
		.240	.305	.340	.425	.570
		.240	.300	.350	.470	.620
		.260	.310	.340	.440	.590
19	620	120	180	240	320	380
		.280	.325	.640	.930	1.700
		.270	.390	.640	.890	1.450
		.260	.340	.660	.900	1.600
20	500	100	160	200	260	300
		.200	.250	.360	.460	.570
		.190	.240	.350	.530	.590
		.210	.250	.370	.510	.580
21	420	80	140	180	220	260
		.220	.325	.470	.440	.540
		.230	.360	.380	.440	.590
		.230	.340	.390	.450	.590

TABLE VI cont...

SUBJECT	MAXIMUM LIFT (LBS.)	20%	30%	40%	50%	60%
22	400	80	120	160	200	240
		.210	.270	.290	.370	.460
		.220	.270	.310	.370	.550
		.240	.280	.300	.390	.480
23	440	80	140	180	220	260
		.210	.270	.340	.410	.520
		.240	.285	.340	.370	.510
		.210	.280	.350	.350	.520
24	400	80	120	160	200	240
		.220	.290	.320	.410	.600
		.230	.250	.310	.410	.620
		.220	.270	.310	.420	.630
25	500	100	160	200	260	300
		.190	.240	.280	.400	.490
		.210	.240	.310	.400	.495
		.210	.260	.320	.420	.490
26	420	80	140	180	220	260
		.220	.370	.460	.470	.740
		.240	.370	.470	.550	.750
		.220	.390	.490	.530	.780
27	440	80	140	180	220	260
		.250	.300	.370	.400	.540
		.240	.330	.370	.440	.530
		.270	.370	.380	.430	.570
28	420	80	140	180	220	260
		.200	.300	.350	.370	.540
		.220	.280	.290	.370	.510
		.220	.290	.290	.380	.530
29	380	80	120	160	200	220
		.230	.315	.360	.450	.510
		.240	.270	.350	.460	.510
		.230	.290	.380	.460	.540
30	720	140	220	280	360	440
		.290	.415	.550	.970	1.230
		.370	.390	.540	1.010	1.300
		.330	.400	.540	.990	1.250
31	420	80	120	160	220	260
		.310	.285	.360	.440	.525
		.260	.280	.330	.440	.540
		.280	.290	.350	.470	.530
32	440	80	140	180	220	260
		.275	.360	.410	.475	.620
		.260	.320	.420	.480	.620
		.270	.340	.440	.480	.640

TABLE VI cont...

SUBJECT	MAXIMUM LIFT(LBS.)	20%	30%	40%	50%	60%
33	420	80	120	160	220	260
		.260	.320	.325	.480	.590
		.360	.290	.330	.480	.570
		.290	.300	.340	.490	.590
34	340	60	100	140	180	240
		.300	.290	.350	.470	.690
		.260	.290	.420	.670	.650
		.290	.320	.390	.520	.680
35	500	100	160	200	260	300
		.300	.420	.540	.535	.750
		.320	.440	.520	.620	.840
		.310	.440	.525	.540	.770
36	340	60	100	140	180	240
		.230	.260	.390	.390	.575
		.200	.290	.360	.470	.535
		.190	.340	.400	.450	.595
37	360	80	100	140	180	220
		.220	.340	.270	.390	.510
		.260	.260	.320	.390	.540
		.230	.290	.290	.430	.530
38	500	100	160	200	260	300
		.270	.355	.440	.690	.800
		.290	.365	.420	.730	.810
		.280	.380	.450	.710	.840
39	460	100	140	180	240	280
		.290	.280	.320	.435	.520
		.260	.290	.320	.470	.520
		.280	.300	.330	.450	.530
40	480	100	140	200	240	280
		.220	.285	.370	.420	.575
		.250	.275	.360	.470	.575
		.260	.290	.370	.440	.580
41	440	80	140	180	220	260
		.240	.300	.360	.480	.560
		.220	.275	.340	.450	.540
		.240	.280	.375	.460	.550
42	420	80	120	160	220	260
		.240	.280	.320	.430	.600
		.310	.280	.320	.420	.600
		.270	.300	.340	.440	.620

TABLE VII

CONVENTIONAL TESTS OF LEG MUSCULAR POWER

SUBJ.	10YD. SPRINT (5YD. RUNNING START)	50YD. SPRINT (5YD. RUNNING START)	STANDING BROAD JUMP	MODIFIED VERTICAL JUMP	BICYCLE ERGOMETER SPEED TEST
1	1.78	7.50	63.50	10.00	27
	1.72	7.40	63.75	11.50	27
	1.74	7.50	66.75	11.50	26
2	1.51	6.50	91.75	18.25	28
	1.64	6.00	95.25	19.50	27
	1.74	6.30	101.00	17.75	28
3	1.59	6.10	77.75	17.50	29
	1.46	6.50	79.50	16.00	27
	1.44	6.20	82.75	17.00	28
4	1.58	7.20	82.50	13.75	24
	1.63	7.00	81.50	15.25	26
	1.55	7.40	79.50	14.50	26
5	1.50	6.20	78.50	14.25	27
	1.46	6.10	82.50	14.25	28
	1.47	6.50	79.00	14.50	27
6	1.54	7.00	74.25	13.75	27
	1.49	6.80	73.25	13.75	27
	1.63	7.00	76.00	13.75	27
7	1.51	7.00	87.00	16.00	24
	1.72	6.60	88.75	16.00	24
	1.63	6.50	92.00	16.00	23
8	1.65	7.00	71.75	13.50	24
	1.50	7.00	76.25	14.50	23
	1.52	7.10	78.75	13.50	24
9	1.51	7.00	90.00	18.25	27
	1.54	7.00	94.50	18.25	26
	1.54	6.80	96.50	18.00	26
10	1.58	7.00	79.50	14.75	26
	1.88	7.20	81.00	14.50	24
	1.75	6.90	80.00	14.00	24
11	1.51	6.60	95.00	19.00	32
	1.51	6.50	92.50	18.50	31
	1.53	6.90	89.75	18.50	32
12	1.53	6.50	77.75	16.50	24
	1.53	7.00	79.50	15.00	25
	1.49	6.50	78.50	16.50	24
13	1.69	7.10	78.00	13.50	27
	1.59	6.90	79.00	12.00	28
	1.65	7.00	79.75	12.50	28

TABLE VII cont...

SUBJ.	10YD. SPRINT (5YD. RUNNING START)	50YD. SPRINT (5YD. RUNNING START)	STANDING BROAD JUMP	MODIFIED VERTICAL JUMP	BICYCLE ERGOMETER SPEED TEST
14	1.50	7.00	73.25	20.25	21
	1.54	6.90	77.25	22.50	23
	1.51	7.20	81.50	22.75	24
15	1.64	7.50	69.00	13.75	23
	1.64	7.50	74.75	13.25	23
	1.68	7.30	73.00	13.75	24
16	1.54	6.50	85.00	17.00	26
	1.56	6.40	88.50	17.25	25
	1.54	7.00	87.00	17.00	26
17	1.52	6.50	85.00	14.00	26
	1.62	6.40	85.75	14.25	28
	1.50	6.90	87.50	14.50	30
18	1.49	6.70	81.50	15.50	26
	1.52	6.80	80.75	14.00	25
	1.60	6.80	81.00	15.25	27
19	1.63	7.10	83.00	14.00	27
	1.61	6.90	81.50	12.50	29
	1.67	7.00	80.00	12.50	30
20	1.42	6.30	97.25	23.75	26
	1.46	6.50	104.00	24.50	27
	1.44	6.60	109.00	24.50	27
21	1.58	6.60	78.50	13.50	29
	1.47	6.90	81.00	14.50	29
	1.55	6.70	79.00	15.00	28
22	1.52	6.60	84.00	15.00	26
	1.49	6.70	87.00	16.25	26
	1.60	6.70	87.00	16.25	26
23	1.43	6.00	92.25	17.75	28
	1.54	6.20	97.50	17.75	29
	1.44	6.00	95.00	19.00	28
24	1.66	6.50	83.00	17.25	28
	1.62	6.10	83.75	17.00	27
	1.47	6.20	81.00	17.75	27
25	1.61	6.50	84.75	16.25	29
	1.58	6.70	85.00	16.25	28
	1.59	6.30	85.50	15.75	28
26	1.52	6.50	80.50	14.75	27
	1.51	6.50	89.25	16.00	27
	1.60	6.70	93.50	17.00	26
27	1.69	6.50	56.00	11.25	27
	1.64	7.00	62.00	13.25	28
	1.53	6.70	65.00	13.50	28

TABLE VII cont...

SUBJ.	10YD. SPRINT (5YD. RUNNING START)	50YD. SPRINT (5YD. RUNNING START)	STANDING BROAD JUMP	MODIFIED VERTICAL JUMP	BICYCLE ERGOMETER SPEED TEST
28	1.53	6.90	92.25	16.50	26
	1.53	7.00	91.75	16.00	27
	1.55	6.80	90.00	16.75	26
29	1.55	6.60	90.50	18.00	27
	1.43	6.50	94.50	17.75	28
	1.49	6.60	96.00	17.75	26
30	1.46	6.10	89.75	17.50	26
	1.44	6.10	89.50	17.00	26
	1.42	6.30	92.75	16.50	26
31	1.69	6.70	88.75	14.50	27
	1.52	6.50	90.75	14.50	28
	1.53	7.00	92.25	13.00	27
32	1.70	6.60	82.25	14.25	25
	1.59	6.90	86.50	14.00	25
	1.65	6.50	84.00	13.75	25
33	1.58	7.00	90.50	19.75	27
	1.39	7.00	95.00	19.00	26
	1.46	6.90	88.50	18.50	26
34	1.45	6.90	79.75	17.00	26
	1.61	7.00	84.00	16.75	28
	1.54	7.00	83.00	16.00	27
35	1.50	6.10	84.75	16.25	26
	1.49	6.20	87.75	16.50	26
	1.50	6.20	91.75	18.50	26
36	1.59	7.00	94.00	17.00	26
	1.51	6.50	97.50	16.50	27
	1.55	6.40	89.50	16.00	27
37	1.58	6.50	65.50	13.75	22
	1.64	6.20	85.00	12.25	23
	1.59	6.70	86.25	14.00	23
38	1.54	6.80	87.25	18.00	30
	1.48	6.50	92.00	17.50	29
	1.50	6.30	91.50	17.75	30
39	1.38	5.90	99.25	19.25	30
	1.48	6.00	102.00	18.75	31
	1.39	6.00	97.75	18.50	31
40	1.29	6.50	91.75	17.00	28
	1.36	6.60	90.25	16.00	27
	1.58	6.70	87.00	16.50	28
41	1.57	7.00	86.25	15.50	25
	1.58	6.90	89.75	15.00	25
	1.64	7.00	87.75	15.25	26
42	1.54	7.00	78.75	18.75	27
	1.52	7.10	76.00	17.00	28
	1.49	7.10	73.75	17.75	28

TABLE VIII

PERCENTAGE OF MAXIMUM LIFT WHICH YIELDED MAXIMUM POWER OUTPUT

SUBJECT	PERCENTAGE OF MAXIMUM LIFT	MAXIMUM POWER	POWER PER POUND
1	52.63	597.94	2.84
2	42.10	643.31	4.64
3	50.00	555.24	3.95
4	40.90	711.45	5.06
5	50.00	597.95	3.83
6	39.13	567.24	3.25
7	52.94	538.15	3.44
8	40.00	430.52	3.09
9	52.38	789.29	4.96
10	52.63	666.28	4.46
11	52.63	555.73	3.61
12	52.94	559.68	3.48
13	50.00	405.56	2.85
14	42.10	611.67	4.53
15	40.00	643.31	4.40
16	49.28	714.31	4.20
17	40.00	752.25	4.45
18	52.38	603.58	3.81
19	28.57	645.78	4.61
20	30.00	728.75	4.05
21	52.38	583.00	3.33
22	40.00	643.31	3.90
23	40.09	732.91	4.19
24	40.00	601.81	4.47
25	40.00	832.86	4.80
26	52.38	545.79	3.26
27	50.00	641.30	3.74
28	42.86	723.76	4.05
29	42.11	533.02	4.18
30	30.56	657.74	4.25
31	52.38	583.00	3.25
32	50.00	540.04	3.41
33	38.09	574.03	4.26
34	41.18	466.40	3.62
35	52.00	566.65	3.22
36	52.94	538.15	3.69
37	38.89	604.59	4.00
38	40.00	555.24	3.99
39	39.13	655.88	3.92
40	50.00	666.29	4.38
41	40.90	617.29	3.95
42	52.38	610.76	3.49

APPENDIX B

TABLE IX (A-E)

THE PEARSON PRODUCT MOMENT CORRELATION COEFFICIENTS

Formula for A-E:

$$r_{xy} = \frac{N\Sigma XY - \Sigma X \Sigma Y}{\sqrt{N\Sigma X^2 - (\Sigma X)^2} \cdot \sqrt{N\Sigma Y^2 - (\Sigma Y)^2}}$$

Where:

N = number of subjects

X = true measure of leg power

Y = conventional test measure of leg power

.3848 was required for statistical significance at the .01 level.

A

The relationship of the true measure of maximum leg power to the Modified Vertical Jump:

$$r_{xy} = \frac{42\ (429567.08) - (25811.81)(697.25)}{\sqrt{42\ (16157811.34) - (25811.81)^2} \cdot \sqrt{42\ (11840.15) - (697.25)^2}}$$

$$= .11$$

(Not significant at the .01 level.)

TABLE IX cont...

B

The relationship of the true measure of maximum leg power to the Standing Broad Jump:

$$rxy = \frac{42\ (2256820.4) - (25811.81)(3663.25)}{\sqrt{42\ (16157811.34) - (25811.81)^2} \cdot \sqrt{42\ (322472.66) - (3663.25)^2}}$$

$$= .11$$

(Not significant at the .01 level)

C

The relationship of the true measure of maximum leg power to the Ten Yard Sprint with the Five Yard Running Start.

$$rxy = \frac{42\ (38785.83) - (25811.81)(63.16)}{\sqrt{42\ (16157811.34) - (25811.81)^2} \cdot \sqrt{42\ (93.03) - (63.16)^2}}$$

$$= -.0057$$

(Not significant at the .01 level)

TABLE IX cont...

D.

The relationship of the true measure of maximum leg power to the Fifty Yard Sprint with the Five Yard Running Start:

$$rxy = \frac{42\ (168951.80) - (25811.81)(275.5)}{\sqrt{42\ (16157811.34) - (25811.81)^2} \cdot \sqrt{42\ (1812.47) - (275.5)^2}}$$

$$= -.18$$

(Not significant at the .01 level)

E

The relationship of the true measure of maximum leg power to the Bicycle Ergometer Speed Test:

$$rxy = \frac{42\ (702932.49) - (25811.81)(1143)}{\sqrt{42\ (16157811.34) - (25811.81)^2} \cdot \sqrt{42(31265) - (1143)^2}}$$

$$= .07$$

(Not significant at the .01 level)

TABLE X (A-E)

THE PEARSON PRODUCT MOMENT CORRELATION COEFFICIENTS

Formula for A-E:

$$r_{xy} = \frac{N\Sigma XY - \Sigma X \Sigma Y}{\sqrt{N\Sigma X^2 - (\Sigma X)^2} \cdot \sqrt{N\Sigma Y^2 - (\Sigma Y)^2}}$$

Where:

N = number of subjects

X = true measure of leg power

Y = conventional test measure of leg power

.3848 was required for statistical significance at the .01 level.

A

The relationship of the true measure of power per pound body weight to the Modified Vertical Jump:

$$r_{xy} = \frac{42\,(2741.70) - (163.86)(697.25)}{\sqrt{42(652.77) - (163.86)^2} \cdot \sqrt{42(11840.15) - (697.25)^2}}$$

$$= .3585$$

(Not significant at the .01 level)

TABLE X cont...

B

The relationship of the true measure of power per pound body weight to the Standing Broad Jump:

$$rxy = \frac{42\ (14358.94) - (163.86)(3663.25)}{\sqrt{42\ (657.77) - (163.86)^2} \cdot \sqrt{42\ (322472.66) - (3663.25)^2}}$$

$$= .3353$$

(Not significant at the .01 level)

C

The relationship of the true measure of power per pound body weight to the Ten Yard Sprint with the Five Yard Running Start:

$$rxy = \frac{42\ (246.07) - (163.86)(63.16)}{\sqrt{42\ (652.77) - (163.86)^2} \cdot \sqrt{42\ (93.03) - (63.16)^2}}$$

$$= -\ .0671$$

(Not significant at the .01 level)

TABLE X cont...

D

The relationship of the true measure of power per pound body weight to the Fifty Yard Sprint with the Five Yard Running Start:

$$rxy = \frac{42\ (1073.05) - (163.86)(275.5)}{\sqrt{42\ (652.77) - (163.86)^2}\ .\sqrt{42\ (1812.47)(275.5)^2}}$$

$$= -\ .212$$

(Not significant at the .01 level)

E

The relationship of the true measure of power per pound body weight to the Bicycle Ergometer Speed Test:

$$rxy = \frac{42\ (\ 4465.89) - (163.86)(1143)}{\sqrt{42\ (652.77) - (163.86)^2}\ .\sqrt{42\ (31265) - (1143)^2}}$$

$$= .1416$$

(Not significant at the .01 level)

APPENDIX C

TABLE XI

RAW DATA OF PILOT STUDY: MAXIMUM LIFT OF EACH SUBJECT AND TIME TAKEN TO LIFT GIVEN PERCENTAGE OF OF MAXIMUM LIFT

SUBJ.	MAX. LIFT	90%	10%	20%	30%	40%	50%	60%	70%	80%	90%
1	380	1.100	.170	.220	.410	.325	.470	.480	.570	.775	.990
		1.570	.110	.220	.280	.325	.450	.490	.590	.785	1.200
		1.010	.120	.220	.175	.340	.390	.500	.580	.840	1.150
2	380	.740	.170	.200	.275	.300	.375	.430	.530	.720	.800
		1.060	.150	.210	.340	.290	.390	.460	.510	.690	.820
		.965	.150	.210	.250	.300	.420	.440	.570	.750	.840
3	400	1.400	.175	.235	.320	.370	.475	.525	.750	1.060	1.520
		1.500	.185	.220	.315	.355	.440	.620	.900	1.140	1.540
		1.650	.160	.225	.300	.370	.420	.590	.735	1.050	1.520
4	440	.975	.160	.200	.270	.295	.380	.470	1.030	.770	.880
		.840	.180	.240	.290	.320	.390	.460	.560	.830	.880
		.900	.170	.195	.300	.320	.400	.460	.550	.820	.920
5	440	1.470	.185	.250	.315	.400	.490	.655	.710	1.390	1.750
		1.500	.150	.240	.290	.390	.520	.620	.770	1.490	1.450
		1.600	.160	.235	.320	.440	.520	.640	.740	1.520	1.600
6	460	1.310	.155	.240	.320	.370	.495	.650	.830	1.430	1.470
		1.800	.160	.235	.320	.380	.540	.680	.970	1.090	1.700
		1.650	.160	.240	.340	.390	.510	.740	.950	1.290	1.540
7	340	1.130	.190	.230	.260	.390	.390	.575	.800	.860	1.030
		1.260	.180	.200	.290	.370	.470	.535	.725	.980	1.420
		1.310	.170	.190	.340	.400	.450	.495	.750	1.040	1.210
8	300	1.390	.190	.215	.300	.350	.450	.515	.700	.990	1.420
		1.650	.170	.215	.280	.540	.450	.525	.690	1.300	1.230
		1.300	.170	.200	.290	.325	.435	.635	.680	.870	1.360
9	420	1.170	.160	.220	.250	.290	.420	.500	.835	.760	1.250
		1.200	.160	.220	.240	.310	.340	.550	.760	.860	1.300
		1.390	.145	.210	.240	.355	.325	.590	.780	.780	1.070
10	380	1.480	.160	.240	.310	.325	.350	.575	.840	1.230	1.650
		1.850	.150	.230	.310	.370	.500	.610	.750	1.160	1.600
		1.660	.150	.220	.300	.380	.490	.580	.710	.980	1.500

TABLE XII

RAW DATA OF PILOT STUDY: PERCENTAGE OF MAXIMUM LIFT WHICH YIELDED MAXIMUM POWER

SUBJECT	MAXIMUM POWER	PERCENTAGE OF MAXIMUM LIFT WHICH YIELDED MAXIMUM POWER
1	597.94	52.63
2	643.31	42.11
3	555.24	50.00
4	711.45	40.91
5	562.90	31.82
6	567.24	39.13
7	538.15	50.00
8	430.52	40.00
9	787.29	52.38
10	666.28	42.11

TABLE XIII

RAW DATA OF PILOT STUDY: STUDENT T-TEST TO DETERMINE IF THERE WAS A SIGNIFICANT FATIGUE FACTOR

$$t = \frac{(\bar{X}_1 - \bar{X}_2)}{\sqrt{\left(\frac{SX_1^2 + SX_2^2}{N_1 + N_2 - 2}\right)\left(\frac{1}{N_1} + \frac{1}{N_2}\right)}}$$

Where: X = mean of group X

$SX_1^2 = X_1^2 - \frac{(\Sigma X_1)^2}{N}$

N = number of subjects

PRE-TEST TIME TO LIFT NINETY PERCENT OF MAXIMUM LIFT X_1	X_1^2	X_2	POST-TEST TIME TO LIFT NINETY PERCENT OF MAXIMUM LIFT X_2^2
1.01	1.02	.99	.97
.74	.55	.80	.64
1.40	1.95	1.52	2.31
.84	.71	.88	.77
1.47	2.16	1.45	2.10
1.31	1.72	1.47	2.16
1.13	1.28	1.03	1.06
1.30	1.69	1.23	1.51
1.17	1.37	1.07	1.15
1.48	2.18	1.50	2.25

TABLE XIII cont...

$X_1 = 11.84$ $\quad X_1^2 = 14.61$ $\quad X_2 = 11.93$ $\quad X_2^2 = 14.92$

$(\Sigma X_1)^2 = 140.19$ $\qquad (\Sigma X_2)^2 = 142.32$

$\bar{X}_1 = 1.18$ $\qquad \bar{X}_2 = 1.19$

$$SX_1^2 = X_1^2 - \frac{(\Sigma X_1)^2}{N} \qquad SX_2^2 = X_2^2 - \frac{(\Sigma X_2)^2}{N}$$

$$= 14.61 - \frac{(11.84)^2}{10} \qquad = 14.92 - \frac{(11.93)^2}{10}$$

$$= 14.61 - \frac{140.19}{10} \qquad = 14.92 - \frac{142.32}{10}$$

$$= 14.61 - 14.02 \qquad = 14.92 - 14.23$$

$$= .59 \qquad = .69$$

$$t = \frac{1.18 - 1.19}{\sqrt{\left(\frac{.59 + .69}{10+10-2}\right)\left(\frac{1}{10} + \frac{1}{10}\right)}}$$

$$= \frac{-.01}{\sqrt{\left(\frac{1.28}{18}\right)\left(\frac{2}{10}\right)}}$$

$$= \frac{-.01}{\sqrt{\frac{.26}{18}}}$$

$$= \frac{-.01}{\sqrt{.014}}$$

$$= \frac{-.01}{\sqrt{.012}}$$

$t = -.833$

(not significant)

*18df (2 tailed T-Test) need 2.10 at .05 level.