SPRINT START TRAINING, PROGRESSIVE RESISTANCE TRAINING AND THE ABILITY TO ACCELERATE TO MAXIMUM VELOCITY

by

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ABSTRACT

The purpose of this study was to investigate the effect progressive resistance training has on the ability to accelerate to maximum velocity from an orthodox sprint start position.

32 subjects were randomly assigned to one of four treatment groups: Group I (Control, n = 9), Group II (Progressive Resistance Training, n = 8), Group III (Sprint Start Training, n = 10), Group IV (Combination Progressive Resistance and Sprint Start Training, n = 5).

Groups II and IV met three times a week for six weeks to weight train using the Universal Machine and barbells. The subjects involved in orthodox sprint start training met three times per week and accelerated a distance of 50 meters for each trial. Each subject performed a total of 20 trials per session.

Testing for the sprint performances occurred at the pre and post tests (first and seventh week). Acceleration and velocity maintenance time in running 50 meters was recorded, with times taken at 5, 10, 15, 20, 30, 40, and 50 meter intervals. The subjects were tested one week after the training had ceased (seventh week) to allow them to recover from the fatiguing effects of training. The Nissen Leg Dynamometer Test for leg extension strength was administered at the end of the third and seventh weeks. The remainder of the tests, Margaria Power Test, Hamstring strength test and Running Machine Test, were administered three times during the experimental period: during the first week, at the end of the third week and at the end of the seventh week.

Analysis of variance yielded no significant difference between the various treatment conditions in sprinting, power and strength performance. No one treatment group improved more than the other. However, there was a significant trials effect in sprint, power and strength performance, for the four treatment groups, showing that there was a significant change in performance by all four treatment groups over the trial period.

The results of this study tend to support those researchers who found no significant improvement in sprinting performance with the use of supplementary program of progressive resistance training. However, the conflict between the conclusions of this study, and other similar studies that found a significant relationship between progressive resistance training and sprinting performance, indicate that there is a great deal yet to be learned about this relationship. Experiments that deal with the application of more specific types of strength training to the art of sprinting, and experiments that investigate the mechanism limiting the rate of leg movement are needed.

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CHAPTER I

INTRODUCTION TO THE PROBLEM

Since the Second World War research into progressive resistance training for strength gains, by such men as Delorme (1946), Houts, Parrish and Hellebrandt (1946), Capen (1950) and Berger (1962), has become accepted as a logical, methodical and scientific approach. A "generality" hypothesis stemming from this research has been accepted by coaches, trainers and many researchers; Clark (1950), Morehouse and Cooper (1967), Marlow and Watts (1970) and Dintiman (1971). This hypothesis states that weight training produces strength gains which will improve the performance in a particular skill.

Normally, locomotion of the human body or its segments will occur when muscular force is applied. Newton's Second Law of Motion (Law of Acceleration) states that the rate of change of momentum is proportional to the impressed force, and the actual change takes place in the direction in which the force acts. A body or its segment(s) accelerates only in proportion to the magnitude of the impressed force. Normally then, force must be applied before movement can occur. For most practical purposes, as far as human locomotion is concerned,

the impressed force is always muscular. Thus, it would appear logical to suggest that while performing progressive resistance exercises using the extensors of the lower limbs, and thereby increasing the muscle's capacity to exert force, that propulsive force can be increased and thus running speed.

Relevant to the question of the relationship between progressive resistance training for increased capacity to exert force and the capacity of speed of movement, Clarke (1950) states that, speed also depends upon strength. This is merely another way of saying that a strong man can lift more than a weak one, or that the strength of a motor limits the speed of an automobile, that is, all other things being equal, the stronger the individual, the faster he can run. Morehouse and Cooper (1950) point out that the importance of strength in accelerating the limbs at high speed is well recognized and determines, to a certain extent, the speed of running. Dintiman (1974) points out that it has become apparent that the strength of the muscles involved in the sprinting action determines, to some extent, the maximum running speed of an individual and states that weight training exercises have constituted the most successful supplementary program in developing the strength of muscles involved in sprinting action, and ultimately in sprinting speed.

The use of weight training following the principles of progressive resistance training, as a supplemental program to sprint training, has become accepted as part of sprint

training programs. There are two basic factors that control sprinting performance, they are: rate of leg movement or strides per second, and drive or stride length. Weight training improves the strength of the extensors of the lower limbs. This improved strength is thought by some authorities, Marlow and Watts (1970), Dintiman (1971) to result in an increase in stride length. The rationale given by these authorities for using this method for strength gains is that if stride length is increased and the rate of leg movement can be maintained, then sprinting performance will be improved. However, a review of the literature related to the topic of the application of progressive resistance and its effect on sprinting speed provides contradictory information. The majority of the studies reviewed appear to support a specificity hypothesis. This hypothesis states that to improve the performance of a particular skill, practise of that skill will be the most beneficial.

Problem

The purpose of this investigation is to determine the effect, over a six week training period, of progressive resistance training on the ability to accelerate to maximum velocity, from an orthodox sprint starting position.

Hypotheses

In light of the present evidence relating to the problem, the following hypotheses were proposed:

(i) No significant difference exists between the sprint start training group (Group III) and the progressive resistance plus sprint start training group (Group IV) in the velocity curve after a six week training period.

(ii) No significant difference exists between the control (Group I) and the progressive resistance training group (Group II) in the velocity curve after a six week training period.

Limitations

This investigation was limited by the sample size of 41 subjects. A more complete investigation into the various methods and effects "strength training" has on acceleration from a sprint starting position might have been undertaken. However, due to the small population size available, it was felt best to thoroughly investigate one method of strength training.

This study was further limited by a change of progressive resistance training activity modes, due to machinery malfunction, from the Universal gym to barbells and weights, during the third week of the experiment. This change of apparatus resulted in a change in the evaluation technique of maximal leg extension strength from the Universal gym to the Nissen leg dynamometer.

This study was also limited by the change of clock counters used to measure the performance in the Margaria Power test for the second (middle) testing period. The change of clock counters meant that there was no second testing period for the 50 meter sprint.

Significance

Many track and field coaches throughout the world advocate progressive resistance training using apparatus for the purpose of improving strength which they feel will improve the athletes' ability to sprint faster. There has been a great deal of research into the degree of generality or specificity that exists between the strength gained in progressive resistance training and the effect this improved strength has on the performance of a particular skill, i.e., accelerating to maximum velocity from a sprint starting position. The results of this research are not clear. This study will attempt to clarify the relationship between one form of progressive resistance training and the ability to accelerate, and reach maximum velocity from an orthodox sprint starting position.

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

The scientific principle of increasing strength by increasing the load or resistance against which the muscles work, has been employed extensively by individuals interested in competitive weight lifting. It has also been used for general strength development in improving athletic performance, as well as in rehabilitating individuals physically weakened by disease or injury.

Delorme (1946), using a method of heavy resistance and low repetition exercises, found that subjects increased their muscular strength. Houts, Parrish and Hallebrandt (1946) also studied progressive resistance activities using heavy resistance and low repetition exercises and found that strength may more than double in four weeks of systematic training.

Varying types of progressive resistance training methods have been used to assess its capability in developing strength. Morant (1970), using isokinetic, isometric and isotonic training programs in increasing strength, found that all methods improved strength. Bergeron (1966) and Bates (1967) studied the effect on the acquisition of strength of

static and dynamic exercises in various positions of a bench press movement. They found all strength training methods improved muscular strength significantly.

Berger (1962a, 1962b, 1965) investigated strength gains involving variation in repetition and set number, as well as weight load lifted with free weights. He came to some interesting conclusions that were incorporated into this experiment.

Berger (1962a) investigated the effect of varied weight training programs on strength in a bench press movement for a period of 12 weeks. He found that 3 sets and 6 repetitions were best for improving strength. In two further studies Berger (1962b, 1965) found that training with submaximal loads was just as effective for improving strength as training with maximum loads. Berger (1962b), over a period of 12 weeks, used a bench press movement for testing strength gains. He found that there was no significant difference between the 90% maximal lift group in performing 10 repetitions. Berger (1965) compared 66%, 80%, 90% and maximal effort lifts on strength gains. He found that there was no significant difference between each group after a 6 week testing period. A squat lifting movement was used as the strength test. Berger's results are significant, for they show a minimum amount of effort required to increase strength.

Specificity and Generality in Motor Learning

Henry and Nelson (1956) stated that individuals have

many specific abilities, rather than a large general factor. One of the major predictions is that intercorrelations among apparently similar motor tasks, will be very low, indicating that there is no common factor upon which the tasks depend. Individual differences in ability to profit by practise are specific to that skill and definitely do not predict the ability to improve by practise in some other skill. Bachman (1961) also concluded that motor learning is remarkably task specific, after experimenting with two large muscle balancing activities. Oxendine's (1966) investigation utilizing both a discrete and a gross motor skill, generally supported the concept of a specificity in the learning and performance of skills.

The concept of task specificity is widely understood and accepted in regard to motor learning. The coach, whether he is the volunteer club coach who at times follows his intuition in applying training methods, or whether he is the physical education specialist who one would hope would apply the principles of motor learning, understands that one does not have athletes train to be sprinters by running large amounts of long, slow running. Nor would the coach have the distance runner train as the weight man does, spending long hours lifting prodigious poundages. To perform a task well, one must practise that task. However, controversy exists regarding the strength gains derived from supplementary activity of progressive resistance training, and the application of this additional strength to a specific skill.

Progressive Resistance Training in Relation to Speed of Movement of a Single Limb

Several studies during the past few years have presented data which reveal the specific nature of muscular neuro-motor activities. Wilkins (1952) found in his study that training with heavy exercise of the resistance type decreased speed of movement and resulted in a decrease in flexibility. A semester program of weight training does not increase speed of movement more than a semester of beginning swimming or golf. Masley et al. (1953), in studies on strength training and speed of arm movement, found that increased strength, gained through a program of weight training where moderate poundages and increased repetitions were practised, apparently bore some association with increased coordination and speed, although it was not demonstrated that increased strength produced better coordination or more rapid movement. Henry and Whitley (1959) in their study on the relationships between individual differences in strength, speed and mass in an arm movement, found that the results agree with the concept that strength as ordinarily measured is determined by a neuro-motor coordination pattern rather than the ultimate physiological capacity of the muscle. The neuro-motor pattern energizing the muscle is different during movement. Lotter (1960) has reported that in the case of a standardized arm movement made with maximal speed, there is 36% general arm speed ability and 64% speed ability that is specific to the right or left arm. There is also a large amount of bilateral neuro-motor speci-

ficity in the speed of leg movements. Clarke and Henry (1961), using weight training for strength increases in a single limb, found that there was no correlation between individual differences in speed and strength mass ratio, but changes in the ratio correlated significantly (r=.405) with individual changes in speed. Pierson and Rasch (1964) used a four week weight training program to determine the effects of general arm strength on reaction time (RT) and speed of arm extension, movement time (MT). They found that the product moment correlation, of RT and MT, was relatively unchanged by four weeks of weight training (r=.47 before and .37 after training). It may be assumed that increases in general arm strength do not affect the speed of reaction or arm extension. Colgate (1966) studied arm strength related to arm speed. He used four groups; speed of movement, speed of movement against resistance, strength and control. The activities in the three groups were the same; horizontal adduction, horizontal abduction, extension from vertical and flexion from horizontal. He found that there was conflicting evidence. He found that there is evidence that a positive relationship exists between gains in speed of movement and gains in speed of movement against a resistance, but it is not conclusive in his study. The relationship between gains in strength and gains in speed against a resistance is not clearly established in his study because some groups had negative correlations and some had significant (.05 level) positive correlations. Mendryk (1966) studied the effect that strength training, using isometric and

isotonic, as well as specific speed conditioning, had upon hip flexion and extension movement time. He concluded that the results of a covariance analysis indicated that significant increases in hip flexion strength are not accompanied by corresponding significant increases in speed of hip flexion movement. Practise of the maximal hip flexion movement by the speed of movement group did not significantly improve leg reaction time or the speed with which the leg could be moved. Smith (1969) reports that the findings of his study support the theory of specificity in that individual differences in the speed of a limb, involving a single joint, are predominantly independent of strength measures associated with the limb and joint.

There have been a number of studies showing positive effects of strength training on the speed of movement of a single limb; Zorbas (1950), Chui (1964), Bergeron (1966), and Bates (1967). Zorbas (1950) in his study on the effect of weight lifting upon the speed of muscular contraction of weight lifters and non-weight lifters, found that the weight lifting group was faster in their muscular contraction of rotary motions of the arm than the non-lifters. Chui (1964) studied the effects of isometric and dynamic weight training exercises upon strength and speed of movement. He found that gains in strength exerted in performing a movement are accompanied by gains in the speed of execution of that movement, against no resistance and against resistance. Gains in strength and gains in speed of movement, against no resistance

and against resistance, made by the use of the one method are not significantly greater (p=.05) than gains made by the use of the other method. In his study, Chui used the same six activities in training and in testing for strength and speed of movement. These activities were; press (right arm), curl (right arm), supine press (right arm), trunk extension (stiff leg dead lift), squat and sit-up. Bergeron (1966) and Bates (1967) both investigated the effect of static strength training at various positions, and dynamic strength training through a full range of motion in strength, speed of movement and power. They found that an increase in strength of the muscles involved in a movement produces a significant increase in the speed of that movement. The method of developing strength, whether by resistance applied throughout the entire movement or isometric exercises at the beginning and/or end of the movement, apparently is not a major factor. Both Bergeron and Bates, in their study, used strength training procedures that involved the bench press movement. Bergeron tested his speed of movement using the bench press motion. However, his subjects were in a standing position.

The majority of studies reviewed suggest the possibility of specificity in the ability to exert force with a particular muscle group in different tasks. Positive effects of strength training on the speed of movement have appeared either when the group superior in the speed of movement has been from a select sample, as in Zorbas (1950), rather than a random sample, or they have practised the desired speed of movement

motion in their strength training, which is in itself specificity of training.

There may indeed be little or no relation between strength in action, as measured by an individual's ability to accelerate the mass of a limb and move it with velocity, and the strength of the involved muscles as measured statically with a dynamometer during a strength test. It is a highly debatable question open to conjecture. Henry and Whitley (1959) state that such an absence of relationship would require considerable revision of current ideas concerning the structure of motor abilities.

Progressive Resistance Training in Relation to Speed of Movement in a Gross Motor Activity

There appears to be a difference of opinion by researchers on the relationship of strength training to speed of movement in a gross motor activity (sprint running). Meisel (1957), Woodall (1960), Hellixon (1961), Sweeting (1963), Blucker (1965), Cummings (1965), Dintiman (1965), Winningham (1965), Schultz (1967) and Morant (1970) have found little or no correlation between strength training and speed of movement. There is a smaller group of researchers who have found a significant correlation between strength training and speed of movement; Capen (1950), Chui (1950), Fishbain (1961), O'Shea (1968) and Barnes (1968).

Meisel (1957) found that progressive weight resistance exercises caused a significant loss of speed in running a distance of 10 yards. Woodall (1960), in his study on weight

training of the arms and upper body and its effect upon speed of high school boys in the 100 yard dash, found that there was no significant speed increases following the weight training program. Hellixon (1961) studied the effects of progressive heavy resistance exercise, using near maximum weights, on the running and jumping ability of first year high school track performers. He found that the proposed training program did not produce a significant effect upon the performance of the experimental group in running a 100 yard dash, as compared to the control group during the experimental period. Sweeting (1963) found that a systematic program of running can improve sprinting speed for a distance of 30 yards, significantly more than a program of weight training or no training outside the testing period. Blucker (1965) found that a four week program designed to increase leg strength had no significant statistical effect on the vertical jumping ability and running speed of a 20 yard run by college women. Cummings (1965), in his study, found that increased hip flexion strength did not provide a significant improvement in running speed over a 100 yard distance. Dintiman (1965), in his study to determine whether a flexibility training program and a weight training program would affect the speed of running 50 yards, found that the weight training program, used as a supplement to sprint training, did not improve running speed significantly more than the sprint training alone. However, a difference in adjusted means of only .01 prevented significance at the .05 level. Winningham (1965) studied the effect of training with ankle

weights on running skill, and found that training with 2 and 5 pound weights reduced 100 yard times. Schultz (1967) studied the relative effectiveness of six intensive training programs on the development of four selected skills; 60 yard dash, standing long jump, zig-zag run and 12 pound shot. He found in his study that the superiority of weight training in the improvement of motor activities was not correlated when it was compared with the intensive training methods. Over the nine week period, the average improvement for the repetition sprint group in the 60 yard dash was .31 seconds and for the weight training repetitive sprint group the average improvement was .33 seconds. The differences between these and the least effective group, weight training, which improved .05 seconds, indicate a need for further study. Morant (1970), in his study on a comparison of exer-genic, isometric and isotonic training programs on selected components of motor ability, found that there was no significant differences between the pre and post training test results for power over a twelve week training period. Morant used a 30 yard timed run as his speed of movement test.

Capen (1950) has been misinterpreted by authorities that have reviewed his study. He investigated the effect of systematic weight training on power, strength and endurance, involving a Sargent running jump, standing long jump, 8 and 12 pound shot put from a standing position and a 300 yard dash. Two groups were used; one involving weight training and the other involving conditioning activities of a calisthenic

nature. Weight training did not improve running speed as has been reported by Dintiman (1974). The conditioning group improved significantly in their 300 yard run times; more so than the weight training group. Chui (1950) investigated the effect of systematic weight training and athletic power as related to jumping, the shot put and sprinting a 60 yard dash. He found that improvement in running speed was only slight. However, there was a possibility that running speed could be aided through systematic weight training. Fishbain (1961) studied the effect weight training programs had upon performance in the 35 yard dash, standing long jump and 20 foot rope climb during a 9 week training period. He found that the experimental group increased significantly more than the control group in the 35 yard dash and long jump. O'Shea (1968) studied the effects of weight training on the 400 meter run. He used an 8 week training period consisting of heavy resistance and low repetitions, with three groups using four sets for the bench press, seated dumbell curl and squat. All three groups improved significantly in both strength and the 400 meter dash (4.4 seconds mean improvement). There was no control group. Barnes (1968) used a 14 week training program to determine the effect of weight training on 100 yard performances of boys (grade 9). One group received 14 weeks of physical education involving basketball, tumbling, volleyball and dodge ball, while the other group spent equal time in progressive weight training using 3 sets of 8 repetitions on half-squat, curls and full knee bends. Both groups weekly ran

two 100 yard dashes for a time, with 15 minutes rest between trials. The weight training group increased significantly from the pre-test (13.4 seconds) to the post-test (12.7 seconds), showing a mean improvement of .7 seconds. In the control group, one subject ran slower and 6 showed no improvement.

The Effects of Various Starting Positions on Speed of Movement

During the first five decades of this century, the investigators of various track starting positions, Hayden and Walker (1933), Dickson (1934) and Kistler (1934), dealt primarily with longitudinal block spacing; elongated 24 to 28 inches, medium 14 to 18 inches and bunch 8 to 11 inches, and its effect on running speed. No conclusive facts were put forth by these investigators as to the best starting position.

In the last two decades there has been an increased amount of study on other variables affecting speed of movement from a track starting position. The variables of force application of front and rear leg, hip height, knee joint angles, distance from the starting line and hand spacing distances have been investigated by Henry and Trafton (1951), Henry (1952), Stock (1962), Menly and Rosemeri (1968), Jackson and Cooper (1971).

Henry and Trafton (1951), in an early study, investigated the velocity curve of sprint running. Twenty-five physical education majors accelerated from starting blocks using a longitudinal toe to toe distance of 18 inches. They ran a distance of 50 yards, with timing devices located at five yard

intervals. They found that sprinting was a two dimensional ability, consisting of an acceleration and velocity component. Most of the acceleration occurred quite early in the dash; 90 percent of the maximum velocity was reached by 15 yards and 95 percent by 22 yards. It was found that the acceleration factor was an important determiner of speed for the first 5 or 10 yards, but not thereafter; whereas the curve constant for the velocity component was important at all distances greater than 5 yards and the only important factor after 20 yards.

Henry (1952) studied the force/time factors of the sprint start. In this study Henry was primarily concerned with the effect that foot placement, i.e. distance between feet, had upon 4 trials of a 50 yard run. Of the 4 longitudinal toe to toe spacings of 11, 16, 21 and 26 inches, he found that the highest proportion of best runs and smallest proportion of poorest runs resulted from starting with a 16 inch stance. A 21 inch stance was nearly as good. Reaction time was uninfluenced by block spacings, and did not correlate with speed in sprints. Leg length was not important in determining the best block spacing and was unrelated to 50 yard sprinting ability. Net times for the 18 subjects using 16 and 21 inch distances in the start, in sprinting 10 yard and 50 yard distances, were superior to the other starting distances. Stock (1962) reported, that by using a medium block spacing (16 inches) and elevating the hips by increasing the angle of the rear knee joint to 165 degrees flexion, sprint times at 50

yards were significantly improved. At the 20 yard mark, the bunch start (11 inches) and the medium start distance (16 inches) with a high hip position, produced significantly faster times. Menly and Rosemeir (1968) reported significantly faster sprint times at 10 yards and 30 yards with a medium toe to toe spacing when the hands and the front foot were placed as close to the starting line as feasible. Jackson and Cooper (1971) investigated the efficiency of the sprinter's start by systematically altering the width of the hand position and angle of the rear knee joint in the set position. The two hand positions with spacings of 8 and 20 inches between thumbs, and three rear knee positions with angles of 90, 135 and 180 degrees were examined. The criterion measures included the 0 to 10 yard distance, 10 to 30 yard distance and the 0 to 30 yard distance. They found that the data offered evidence to support the use of the narrow hand spacing. The 90 and 135 degree rear knee joint angles did not differ significantly in results, but were superior to the 180 degree knee joint angle.

Summary of Studies

All the studies dealing with weight training and its influence upon speed of movement in a gross motor activity, dealt with the subjects running various timed distances, from 10 yards to 100 yards. These studies found that weight training programs did not increase running speed, and were found to decrease running speed in the studies done by Meisel,

Sweeting and Winningham.

The studies that showed a positive relationship between weight training and speed of movement also had the subjects run various distances, from 35 yards to 400 yards.

One important point to remember when considering the effect of weight training on the speed of movement (sprinting) is the control of the athlete's starting position. Henry and Trafton (1951) have shown that sprinting ability is made up of two dimensions: positive acceleration and velocity. None of the studies mentioned in the review of literature looked at the effect weight training had upon either of these two factors. If the studies were investigating the effect weight training had upon acceleration, then consideration of the many important components of a sprint starting position such as the distance the feet are apart or the angle of the front and rear knee in the set position, etc., would have to be given. If the studies were investigating the effect weight training had upon velocity, then consideration of running fundamentals, i.e., good sprinting form and the ability to maintain velocity after 6 seconds, the distance Henry has theorized that is required to reach optimum velocity, would have to be studied. Schultz does not mention how the subjects started when they ran 60 yards. Dintiman used a running start then timed the individuals for 50 yards. He did not state the distance used in the running start. Morant used a 10 yard running start, then timed the subjects for 30 yards. Blucker and Fishbain allowed their subjects to start using any method they preferred. They

had a 30 foot running start before they were timed for 20 yards. Sweeting and O'Shea used a standing start with subjects starting when they were ready. Hellixon, Fishbain, Chui and Meisel allowed their subjects to assume any starting position. They did not specify the type of position. Woodall and Barnes allowed their subjects to choose their own crouch start position and then a starting signal was given. Cummings used an unspecified length running start when timing his subjects over 100 yards. Winningham used starting blocks in his study allowing the subjects to assume a semi-crouch position. He does not elaborate further on the starting position. Because the studies mentioned in the review of literature did not consider the importance of the factors affecting either acceleration or velocity their results should be looked upon critically.

All of the studies dealing with various track starting positions on speed of movement have dealt with the subject running 50 yards from various starting positions. Henry and Trafton (1951) controlled only one toe-to-toe distance; 18 inches. Henry (1952) controlled only toe-to-toe distances of 11, 16, 21 and 26 inches, finding the 16 inch spacing to produce the best results. Stock (1962) controlled longitudinal block spacing and rear knee angle and found the 16 inch spacing with a rear knee angle of 165° produced the best results at 50 yards. Jackson and Cooper (1971) controlled the toe-to-toe distance of 16 inches, rear knee joint angle and hand width distance. They found that a shoulder width spacing of the

hands, with rear knee angles of 90° and 135° to produce the best results at 50 yards. It would appear that best results in a sprint start position would come from a medium block spacing (16 inches), a rear knee joint angle less than 180° and a shoulder width spacing of the hands. However, not all of the variables associated with the starting position have been considered. A shoulder width spacing of the hands was found to be most effective, but what of the angle formed between the trunk and the arms when looking at a profile of the runner in the set position?

Tricker and Tricker (1967) found that during a sprint the height of the runner's center of gravity is an index of his rate of movement. In the set position in a track starting position the position of the runner's center of gravity in relation to his driving force; muscles of the lower limbs is critical. If the center of gravity is too far forward of the accelerating force, that is a low center of gravity, the runner is too unbalanced and will rotate forward in a sagital plane around the axis of his feet. If the runner's center of gravity is too far back over his accelerating force, that is a high center of gravity, he will have the tendency to rotate backward in a sagital plane around the axis of his feet. Therefore, an angle of 90° between the arms and the trunk would be one in which the weight of the runner is balanced between the four points in contact with the ground.

By controlling the many variables in a sprint start, the effects of a strength training program on an individual's abil-

ity to either accelerate or maintain velocity would become clearer. What would the effect of a strength training program have on the ability of a person to run 50 meters from a standardized start position? Henry (1952) feels that individuals with a large acceleration or a small acceleration component are equally likely to be good 50 yard sprint runners. Therefore, assuming that a sprinter had the capacity for high velocity, could a strength training program have a positive and significant effect on his ability to accelerate? Even if a runner did not have this high velocity capacity, could his acceleration be positively affected through a strength training program?

A sprinter's ability to accelerate and maintain velocity results from a combination of stride rate or leg speed, and drive or stride length. Slater-Hammel (1941) feels that there is a neuromuscular mechanism limiting the rate of leg movement in sprinting. If this neuromuscular limiting factor does not inhibit rate of striding what effect would a strength training program have on a sprinter's ability to accelerate or maintain velocity.

The researchers who studied the effect that progressive resistance training had on the speed of movement of a gross motor activity measured only the change in sprint performance time for the complete distance run. Thus, the issue of progressive resistance training and its effect on acceleration or velocity maintenance is clouded.

CHAPTER III

METHODS AND PROCEDURES

Subjects

A sample of 48 subjects were chosen from volunteers from a university activity class in track and field. The subjects were randomly assigned to one of four groups in the manner of 10 males and 2 females to each group, except in the progressive resistance group, where 3 females were randomly assigned to it. During the first 3 weeks of the experimental period, 2 males dropped out of Group II, progressive resistance training, and 5 males and 1 female dropped out of Group IV, the combination progressive resistance and sprint start training group. The reason given for the subjects' withdrawal from the experiment was heavy physical training demanded in the experiment was detrimental to their studies. The experiment continued into the final exam period for the university. One male subject's data from the control group was not analyzed because of his extreme variability in performance.

Only the 32 male subjects' data were statistically treated in this experiment. The females were excluded because of the large inequality in number between males and females in

each treatment condition. Group I (control) was comprised of 10 males and 2 females; Group II, (progressive resistance training) was comprised of 8 males and 3 females; Group III, (sprint start training) was comprised of 10 males and 2 females and Group IV, (combination progressive resistance and sprint start training) was comprised of 5 males and 1 female.

Subjects had a mean age of 20 years. The mean weight and height for males was 72.7 kilograms and 1.79 meters respectively.

Experimental Design

The experimental design for this experiment consisted of 4 groups: Group I (control), Group II (progressive resistance training), Group III (sprint start training), and Group IV (combination progressive resistance and sprint start training). These 4 groups were to be tested 3 times over the experimental period. However, due to apparatus breakdown some of the dependent variables were only tested twice. The dependent variables that were tested twice were: 50 meter sprint with velocity recorded at distances of 5, 10, 15, 20, 30, 40, and 50 meters. Leg extension strength was also measured twice, at the mid and post testing periods, on the Nissen Leg Dynamometer. The dependent variables that were tested three times (pre, mid, and post) were: Leg extension strength as measured on the Butkus running machine, Hamstring strength as measured

		Pretrial time 1	Posttrial time 2
GROUP I	Males S_1 S_{10}	Dependent Variables:	
GROUP II	Males S_1 S_8	1. 50 meters (times taken at 5, 10, 15, 20, 30, 40, and 50 meters.	
GROUP III	Males S_1 S_{10}	2. Nissen Leg Extension Dynamometer.	
GROUP IV	Males S_1 S_5		

Figure 1 4 x 2 Factorial Design

		Pretrial time 1	Midtrial time 2	Posttrial time 3
GROUP I	Males S_1 S_{10}	Dependent Variables: 1. Margaria Power Test (measured in Kilogram.meters per second). 2. Leg extension strength (as measured by the Hamstring Machine, and Running Machine)		
GROUP II	Males S_1 S_8			
GROUP III	Males S_1 S_{10}			
GROUP IV	Males S_1 S_5			

Figure 2 4 x 3 Factorial Design

on the Hydraulic Hamstring machine, and Anaerobic Power as measured on the Margaria Power Test. Figure 1 and 2 illustrate the experimental design layout.

Apparatus

50 Meter Sprint. The equipment used in the 50 meter run from a standard track starting position was as follows:

1 set of Gill Model 95 starting blocks

4 standard laboratory goniometers - used to measure the angles at the shoulders, between the trunk and arms and the angles of the front and rear legs at the knees. These measurements were taken on the mid-line of the limbs.

7 Armaco photo-electric cell systems - located at 5, 10, 15, 20, 30, 40 and 50 meter distances from the start line during the two test periods.

2 Lafayette clock/counters

2 Hunter timers

2 Healy Microswitches

The two Lafayette clock/counters were to be used for three testing periods: pre, mid and post. The Lafayette Digital Clocks were not available for the mid or post tests and two Hunter timers were used as alternative clocks.

During the pre test, the two Lafayette clock/counters were connected to the 7 sets of photo-electric cells in such a way that the release of pressure on the microswitches started clock 1. When the subject broke the photo-electric cell 1, clock 1 stopped and clock 2 started. As the subject pro-

gressed down the 50 meters he continued to break the beams of the photo-electric cell. This breaking of the beams alternately stopped and started each clock. When a subject had completed his run, clock 1 had an accumulated time of distances 0 to 5, 10 to 15, 20 to 30 and 40 to 50 meters. Clock 2 had an accumulated time of distances 5 to 10, 15 to 20 and 30 to 40 meters. (See Figure 3). All of the times taken to run between the photo-electric cells were recorded for each individual on each trial. The recorder for clock 1 recorded the time taken from 0 to 5, 10 to 15, 20 to 30 and 40 to 50. Another recorder recorded the clock 2 times for the distances of 5 to 10, 15 to 20 and 30 to 40 meters.

During the post trial the same 7 sets of Armaco Photo-Electric Cells were used, but two Hunter timers were substituted for the Lafayette clock/counters. The Hunter timer required 3 relays to energize and de-energize each clock as the subject broke the beams of the photo-electric cells. The times taken by the subjects were recorded on each clock in the same manner as the times on the Lafayette clock/counters.

Margaria Power Test. The apparatus used for the Margaria Power Test was as follows:

2 sets of Armaco Photo-Electric Cell Systems

1 Lafayette clock/counter

1 Hunter timer

The pre, mid and post tests were completed using the same two sets of Armaco Photo-Electric Cell Systems. The Lafayette

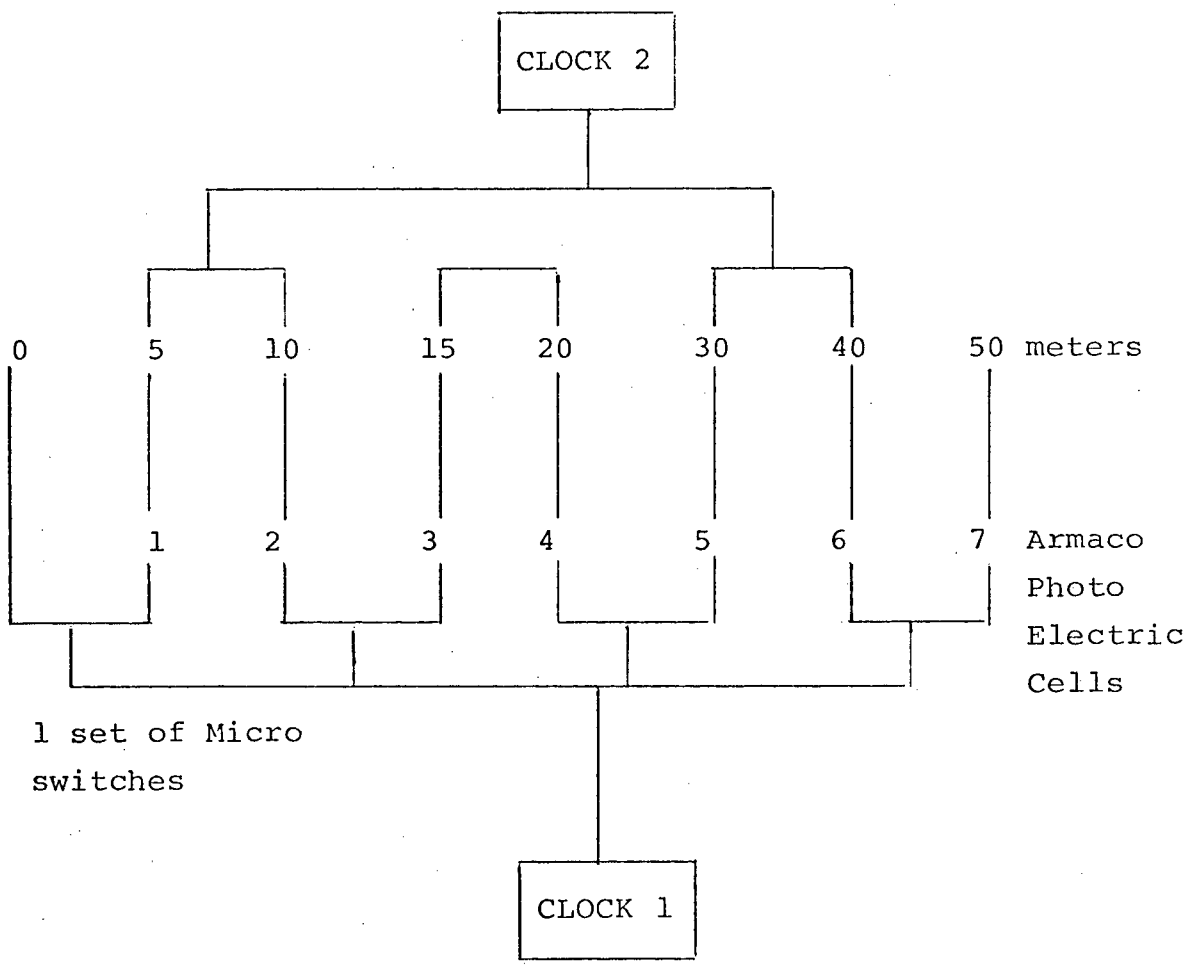

Figure 3 Design Layout of the Retrieval of the Acceleration times in the 50 Meter Sprint

clock/counter was used in the pre and mid tests. The Hunter timer was used for the post test.

Running Machine. The Butkus Running Machine 1972 was used for this test. Resistance to a running motion while the subject was in a prone position, was supplied by a friction brake. The amount of friction could be controlled and was measured in pounds pressure. A Hanhart Mechanical Split-Hand Stop Watch was used to time the work intervals.

Hamstring Machine. A Universal Goliath Hydraulic Hamstring Machine was used to test the strength of each subject's hamstring muscle group. The hydraulic machine applied a constant force against which the hamstring worked. Resistance could be controlled by adjusting the pressure in the hydraulic cylinder. Resistance was read in pounds per square inch. A Hanhart Mechanical Split-Hand Stop Watch was used to time the work interval.

Universal Machine. The Universal Spartacus Model 9500 was used to test leg and ankle extension strength in the pre-test. Resistance could be controlled in this pulley operated machine. The resistance was read in pounds.

Nissen Leg Dynamometer. The Nissen Leg Dynamometer Model 750 was used to test leg extension strength in the mid and post tests. Force application was read in pounds pull x 10.

Barbells and Discs. The university set of Weider barbells and discs was used to train in the squat motion and in ankle extension. The amount of resistance was controlled by using a heavier poundage of barbells. The poundages ranged from 50 to 250 pounds.

Procedure

The progressive resistance training that was followed by the respective groups was in two forms. The original design of the study was to use the Universal Machine, the Butkus Running Machine and the Hamstring Machine. A total of four progressive resistance training exercises were performed on these machines. The exercises consisted of exercises that would strengthen the flexors and extensors of the lower limbs:

(i) Leg and ankle extension performed on the upper pedals of the Universal Machine and performed from a starting position of 90° at the knee and ankle.

(ii) Leg extension performed on the lower pedal of the Universal Machine from a starting position of 90° at the knee and ankle.

(iii) Extension and flexion of the lower limbs, performed on the Butkus Running Machine, with the subject resting his chest, at a 30° prone position. He placed his feet in stirrups and alternately brought his legs through a running motion of flexion and

extension. Resistance was controlled.

(iv) Hamstring exercise performed on the Hydraulic Hamstring Machine.

At the start of the third week of training the Universal Machine broke down. This predicament necessitated a change to another form of progressive resistance training; weight training with barbells and discs. The barbell and disc weights were used for only two activities:

(i) squat lift performed with the weight supported on the shoulders. The subject then performed a sitting action until his upper and lower legs formed a 90° angle at the knee. The heels were supported on a 3 inch piece of wood to provide stability throughout the movement.

(ii) ankle extension performed with the weight supported on the shoulders. The subject placed the front portion of each foot (ball) on an elevated (3 inches) piece of wood. The subject then shifted his weight by extending his ankle so that in the final position of this exercise he stood upon the piece of wood on his toes only.

These two activities replaced the activities performed on the Universal Machine.

Training Program. The progressive resistance training and sprint start training program followed by the subjects was organized in the

following fashion:

(i) Period I (First, second and third week)

(a) 3 workouts per week for the progressive resistance training group (Preparation Phase, consisting of 3 sets with 12 repetitions and 3 sets of 15 repetitions).

(b) 3 workouts per week for the sprint start training groups (consisting of twenty 50 meter accelerations).

(c) 6 workouts per week for the combination group (consisting of progressive resistance and sprint start training).

(ii) Period II (Fourth, fifth and sixth week)

(a) 3 workouts per week for the progressive resistance training group (heavy lifting, pyramid system, 3 sets with 6 repetitions, 3 sets with 6 repetitions and 3 sets with 6 repetitions, increasing the load shifted in each set).

(b) 3 workouts per week for the sprint start training group (consisting of twenty 50 meter accelerations).

(c) 6 workouts per week for the combination group.

The two groups, progressive resistance and the combination group, met three times a week to weight train. The six week training period was divided into two sections of three weeks

each. The first three weeks were a preparation phase consisting of relatively light loads and high repetitions and sets, i.e. 3 sets of 12 repetitions at one weight and 3 sets of 15 repetitions at a heavier weight (3 x 12 and 3 x 15).

This period was to be used as an acclimatization period for the subjects, as the majority of those subjects that participated in the study had no experience with weight training. During the third week the subjects increased the weight in both the 3 x 12 and 3 x 15 progressive resistance sets by 40 pounds in the squat lift and 20 pounds in the ankle extension. The strength of the subjects had increased enough, and thereby their acclimatization to hard muscular work, to move into the second phase of the study.

It was at this time that the Universal Machine broke and progressive resistance training with the barbells and discs was employed. Proper technique for performing a squat lift and ankle extension with free weights was taught. Supervision of the subjects during training was done to insure that good technique was employed to prevent injury.

The results of Berger's (1962a, 1962b, 1965) studies were used as the basis for the progressive resistance training done in this experiment. It was felt that Berger's results would be used as the basis for progressive resistance training because the University's barbell weights did not total to a heavy enough poundage to train at over 80% of maximal strength.

The pyramid system used in this study consisted of 3 sets of 6 repetitions. Each subject started with a weight

appropriate to the completion of 6 repetitions such that the last 2 repetitions were quite difficult. The weight was increased for the next six repetitions and the last six repetitions, following the same procedure. To safeguard against injury increments of only 20 pounds were used from one set to the next.

The progressive resistance training and combination group did not do their progressive resistance training together. It was felt that if they did train together then the performance of the subjects in each group would have a detrimental influence on each other's performance in training. The sprint start and combination training groups did not do their sprint start training together for the same reason.

In the sprint start training the following variables in the set position were controlled during each trial run for each individual:

(i) Hand-to-hand distance (laterally). Each individual had the distance measured for them. This marked distance was placed on the ground. It was the distance between thumbs when the arms were directly under the shoulders.

(ii) A 90° angle between trunk and arms taken on the midline of the arms and trunk.

(iii) The toe-to-toe longitudinal spacing of 16 inches for each individual.

(iv) Front knee joint angle of 90°.

(v) Rear leg knee joint angle of 120°.

Both rear and front leg knee joint angles were taken on the midline of the upper and lower leg. The subjects wore flats to perform each trial. Each subject performed a total of 20 trials per session. Enough rest, 15 minutes, was given to ensure reliability of performance. Each individual was urged to make each trial a maximum. The subjects involved in sprint start training met three times per week and ran a distance of 50 meters for each trial.

The variables that were controlled in the orthodox sprint start position were the ones considered most important by the researchers as laid out in the review of literature section. The measuring of the various angles for each subject was carried out by other subjects. All subjects were taught the proper techniques of measurement and were supervised throughout the study.

Each subject assumed the set position when they were ready. The measurements of the angles at both knees and at the shoulders were taken. The subject was given the command "good" if all the angles were all right, i.e. front knee at 90°, rear knee at 120° and trunk at 90°. If the subject did not assume the desired position he was given verbal cues such as "up, forward, down, back," etc. to assist in assuming the proper position. Once the subject had assumed this position he held the position for practise purposes to acquire a feel

for the various positions of the front and rear legs and trunk. He then went down to the "on your marks" position to rest his fingers, and when ready he assumed the set position again. If the angles at the knees and shoulders were correct he initiated running on his own response. This procedure worked very well. It was found that after the second week of training, the subjects assumed the set position with very few adjustments of body angles.

There was no training for the control group. They were told not to change their life style drastically during the six week training period, as this would affect their test scores.

Testing. The test which was chosen to be used in this study to evaluate the effects of progressive resistance training on the ability to sprint 50 meters from an orthodox sprint starting position, was running 50 meters from an orthodox sprint starting position, with times taken at 4, 10, 15, 20, 30, 40 and 50 meters. Testing occurred at the beginning of the experimental period and at the end (first week and seventh week). The subjects were tested one week after the training had ceased (seventh week) to allow them to recover from the fatiguing effects of training.

The Nissen Leg Dynamometer Test for leg extension strength was used at the end of the third and seventh week. The remainder of the tests, Margaria Stair Run, Hamstring Strength and the Running Machine, were administered three times during the experimental period; during the first week,

at the end of the third week and at the end of the seventh week.

All testing was carried out at the University of British Columbia. Upon arrival at the testing site, one hour before the testing, each subject was asked to rest for 15 minutes and read the instructions for testing procedure (See Appendix A).

The maximum strength of each subject was assessed on the Universal Machine by using the one maximum repetition test. This procedure consisted of having the subject warmed up for maximum effort and then performing an extension movement against the heaviest resistance that the subject could move in one maximum effort. The procedure followed to determine the maximum resistance for each subject was as follows:

(i) Resistance was set at 600 pounds for males and 300 pounds for females, in the upper pedal leg extension position.

(ii) Resistance for ankle extension was set at 550 pounds for males and 250 pounds for females.

The subjects were allowed 3 increases or decreases from the above poundages to determine maximum resistance. If the subject could not complete extension, the resistance was reduced by 20 pound segments until the resistance could be moved. If the resistance was too light, 20 pound segments were added until maximum effort was required to move the resistance. The rest between maximum repetition efforts was

15 minutes. This time allowed for recovery. If the subject could not find the resistance that required maximum effort in 3 trials they returned the following day.

For the Nissen Leg Dynamometer Test the subjects wore a webbed belt that had additional towelling placed between it and the subject. The belt had a hook that was located in the front. The subject stood on a bench with his back flat against the wall. His shoulders were forced against the wall by other subjects. The subject assumed a crouching position with his back flat against the wall. A chain was attached to the hook in the belt. The slack was taken up. The angle at his knees was measured at 120°. When the subject was ready he applied maximum effort into standing up (extending his legs). The force that was being applied by the subject against the chain was recorded. When the subject could no longer apply an increasing amount of force he was told to relax. Each subject performed one trial at the mid and post testing periods of the experiment.

The test for Hamstring strength was performed on the Hydraulic Hamstring Machine. Resistance was controlled by hydraulic pressure. The subject assumed a prone position hooking his heels under a padded bar. When the subject was ready he applied maximum effort in flexing his lower legs to a 90° angle at the knees. Initial resistance was set at 11 pounds/square inch for males and 10 pounds/square inch for females. The subject was timed during his trial and if the time for maximum effort took longer than 10 seconds, the trial

was terminated. The subject was allowed only 2 trials to establish maximum resistance with a time of 15 minutes between each trial. If maximum resistance could not be established, the subject returned the next day.

The procedure followed for the 50 meter run was the same as outlined in the sprint start training section. The only difference during the test was that in the set position the subjects depressed two microswitches, one with each thumb. When the runner initiated forward running motion, he released the two microswitches and started the clock running. Each subject performed three trials, with the best trial recorded taken as being representative of the individual's best effort. The subject was given 10 minutes rest between trials.

The Margaria Stair Run is a test of leg power. The subjects were instructed to run at top speed up ordinary stairs, two steps (17.5 cm. each) at a time. The time employed to cover an even number of steps was measured with an electronic clock sensitive to .01 seconds, driven by two photo-electric cells. The light beams ran parallel to the steps and were interrupted by the running subject. The reason for an even number of steps was to have the subject intercept the beam of light while in the same phase of the movement. The vertical component of the speed was easily calculated by knowing the vertical and horizontal dimensions of the step. For the measurement of the power, the time taken from the fourth to sixth jump (70 cm. height) was recorded. The procedure followed was the same as outlined by Margaria (1968). Each subject was

given three trials and told to run them at maximum speed. There was a 10 minute rest between trials. The best effort (time) was used as being the individual's best effort.

The maximum number of leg extensions and flexions during a 10 second trial was the basis for the running machine test. The resistance for the males was constant at 260 pounds; the resistance for the females was 170 pounds. These resistances were arrived at through previous testing of students that were participating in a fitness program. They were a group of physical education students, male and female, at the University of British Columbia. It was felt that the resistance used on these subjects was adequate for the subjects in the experiment. The subjects rested their chests on a support (30° angle). The subjects could slide their chests up or down on the support. They were shown where to position themselves for each trial so that during flexion of each leg, an angle of 90° was formed between the trunk and the flexing leg. To count one repetition the subject had to perform complete extension and flexion with one leg. Each subject performed three trials, with the best trial recorded taken as being representative of the individual's best effort.

Testing Parameters. The three experimental testing periods measured the following parameters of strength, power and speed:

(i) Total time taken to run 50 meters from an orthodox track starting position.

(ii) Acceleration and velocity maintenance time in

running 50 meters.

(iii) Maximum anaerobic power as measured by the Margaria Power Test.

(iv) Maximal leg extension strength as measured in a one maximum repetition on the Nissen Leg Dynamometer.

(v) Maximal hamstring strength as measured on the Hydraulic Machine during a 10 second interval.

(vi) Maximal number of leg extensions and flexions during a 10 second trial on the Butkus Running Machine.

Statistical Analysis

The mean scores from the five dependent variables were subjected to an analysis of variance in either a 4 x 2 or 4 x 3 factorial design. An analysis of variance tested the validity of Hypotheses 1 and 2. The significance for the difference between correlations was computed using Fisher's Z Transformations. Critical values of the correlation coefficients were also computed to determine the level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

Results

The results of this investigation, regarding the effect progressive resistance training has on the ability to accelerate to maximum velocity from an orthodox sprint start are presented in this chapter. The initial phase of the analysis examined the raw scores compiled from all subjects observed during the six week testing period (see Appendix B).

The mean scores of the four groups on the five tests (50 meter sprint, Margaria Power Test, Hamstring Test, Leg Dynamometer Test and Running Machine Test), were calculated for the three testing periods and are presented in Tables 1 to 6.

Analysis of Variance

The data was then subjected to an analysis of variance with a separate ANOVA being performed for each of the five dependent variables (see Appendix C).

The sprinting performance for the four treatment conditions showed a marked improvement from trial 1 to trial 2. This difference is shown in the trials main effect ($F = 9.20$,

TABLE I

Mean Velocity Scores Obtained From the Test of Sprinting Performance for Trial Periods 1 and 3 (Measured in m./sec.)

Trial 1

	5 m.	10 m.	15 m.	20 m.	30 m.	40 m.	50 m.	Ave. Vel.	50 m. Time
Group I (Control)	3.46	6.73	7.20	7.61	8.00	8.01	7.69	6.81	7.34
Group II (Progressive Resistance)	3.43	6.68	7.19	7.55	8.01	7.81	7.54	6.71	7.45
Group III (Sprint Start)	3.56	6.95	7.38	7.86	8.19	8.03	7.69	6.94	7.21
Group IV (Combination)	3.46	6.80	7.33	7.45	7.78	7.87	7.76	6.75	7.41

Average Velocity Over Groups 6.80 Average 50 m. Final Time Over Groups 7.35

Trial 3

	5 m.	10 m.	15 m.	20 m.	30 m.	40 m.	50 m.	Ave. Vel.	50 m. Time
Group I	3.52	6.63	7.24	7.79	8.06	8.12	7.67	6.84	7.31
Group II	3.53	7.19	7.52	7.54	7.84	7.88	7.79	6.84	7.31
Group III	3.75	7.14	7.53	7.89	8.30	8.21	7.91	7.09	7.05
Group IV	3.58	6.95	7.10	7.25	8.05	7.90	7.72	6.82	7.33

Average Velocity Over Groups 6.90 Average 50 m. Final Time Over Groups 7.25

TABLE II

Mean Power Scores Obtained from the Margaria Power Test for Trial Periods 1, 2, and 3 (measured in kilogram.meters per second)

	Trial 1	Trial 2	Trial 3
Group 1	114.01	125.60	114.13
Group 2	109.97	120.65	111.26
Group 3	115.82	119.19	119.94
Group 4	123.73	133.62	131.35

TABLE III

Mean Velocity Scores Obtained from the Margaria Power Test for Trial Periods 1, 2, and 3 (measured in meters/sec.)

	Trial 1	Trial 2	Trial 3
Group 1	1.45	1.67	1.51
Group 2	1.50	1.65	1.52
Group 3	1.60	1.64	1.65
Group 4	1.50	1.62	1.60

TABLE IV

Mean Scores Obtained from the Hamstring Strength Test for Trial Periods 1, 2, and 3 (measured in pounds per square inch)

	Trial 1	Trial 2	Trial 3
Group 1	11.00	12.40	12.60
Group 2	11.75	12.63	12.88
Group 3	11.20	12.60	12.90
Group 4	11.60	12.60	12.80

TABLE V

Mean Scores Obtained from the Nissen Leg Dynamometer Test for Trial Periods 2, and 3 (measured in pounds pull)

	Trial 1	Trial 2	Trial 3
Group 1	-----	1,102.0	1,196.0
Group 2	-----	941.3	1,086.0
Group 3	-----	1,021.0	1,074.0
Group 4	-----	1,098.0	1,166.0

TABLE VI

Mean Scores Obtained from the Running Machine Test for Trial Periods 1, 2, and 3 (measured in Leg Extensions per 10 seconds)

	Trial 1	Trial 2	Trial 3
Group 1	13.00	14.50	15.00
Group 2	13.00	15.00	16.00
Group 3	13.50	14.00	15.00
Group 4	13.00	15.00	15.00

$p<.01$) and can be observed in Figure 4. However, no one group following any one method of training improved more than any other group.

A significant trials effect was also shown for the Leg Dynamometer Test ($F = 8.90$, $p<.01$), Margaria Power Test ($F = 8.69$, $p<.01$), Running Machine Test ($F = 16.74$, $p<.01$), and Hamstring Machine Test ($F = 55.80$, $p<.01$) and can be observed in Figures 5 to 8, respectively. The significant trials effect shows that there was a significant change in performance by all four treatment groups over the trial periods. The type of progressive resistance training done, and the procedures followed in doing the training support Berger's (1965) method of progressive resistance training, i.e., training at sub-maximal loads.

The condition and the trials by condition effects were non significant for all dependent variables. This shows that there were no differences among the four groups in average performance, and also that the change over trials was the same for each group.

The data was then subjected to a test of significance between two correlation coefficients for independent samples. This test was performed to determine whether the correlation between two variables within one group was significantly different from this correlation for another group. The significance of the difference between correlations was computed using Fisher's Z Transformations. A direct comparison of correlations between groups revealed that the differences be-

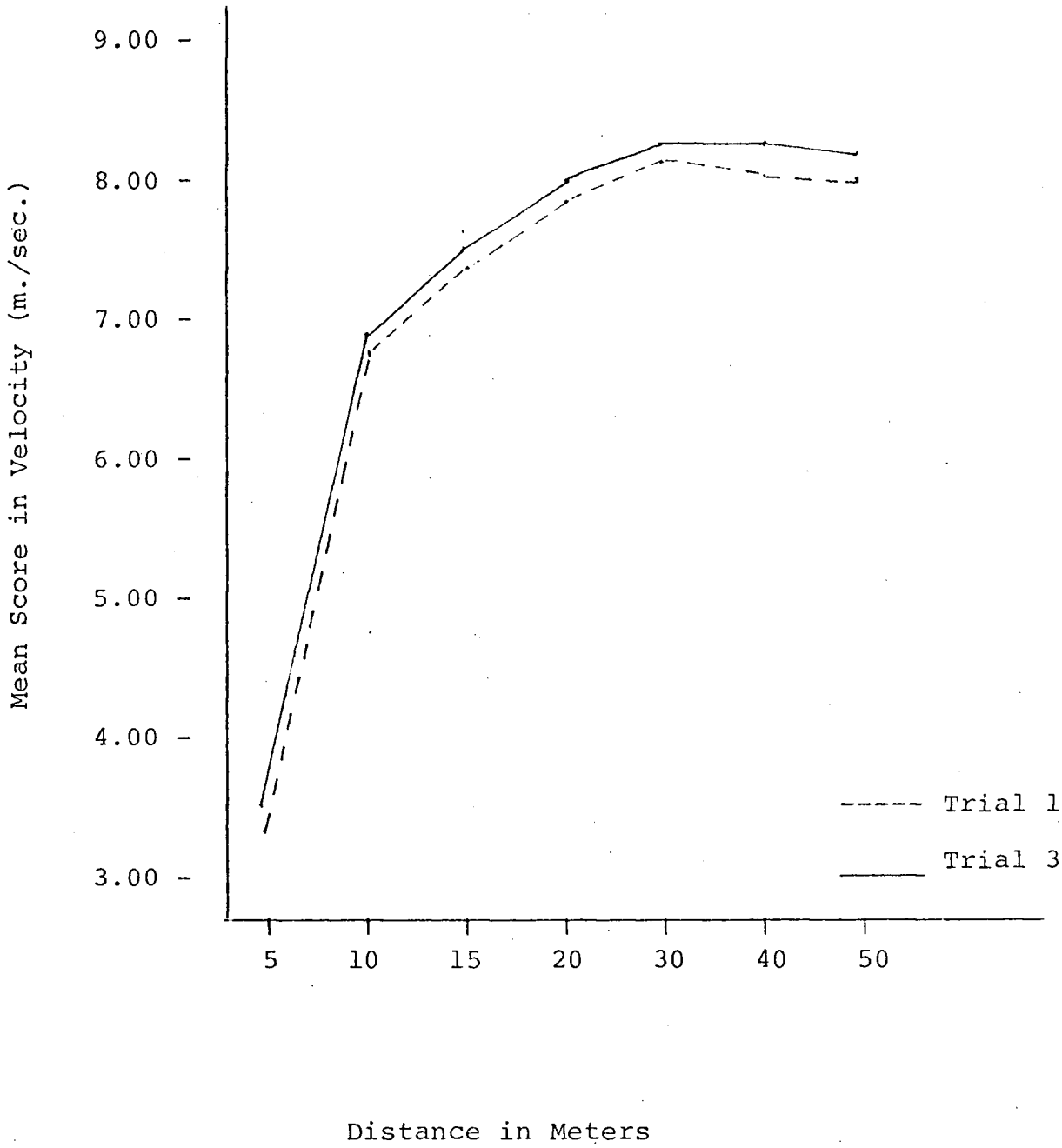

Figure 4 Mean Sprinting Performance in Velocity for the Four Treatment Conditions during trial periods 1 and 3

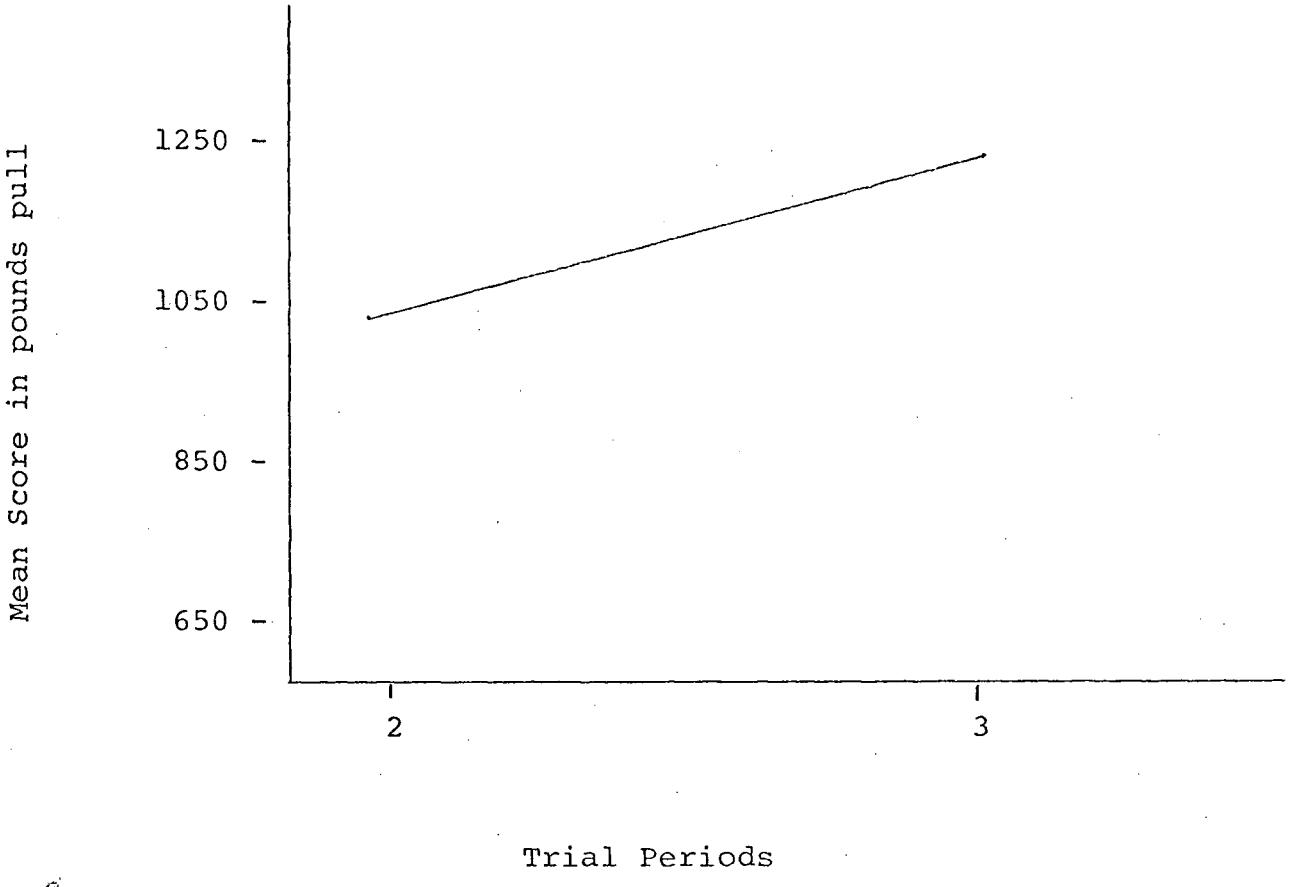

Figure 5 Mean Strength Performance in Nissen Leg Dynamometer for the Four Treatment Conditions During Trial Periods 2 and 3

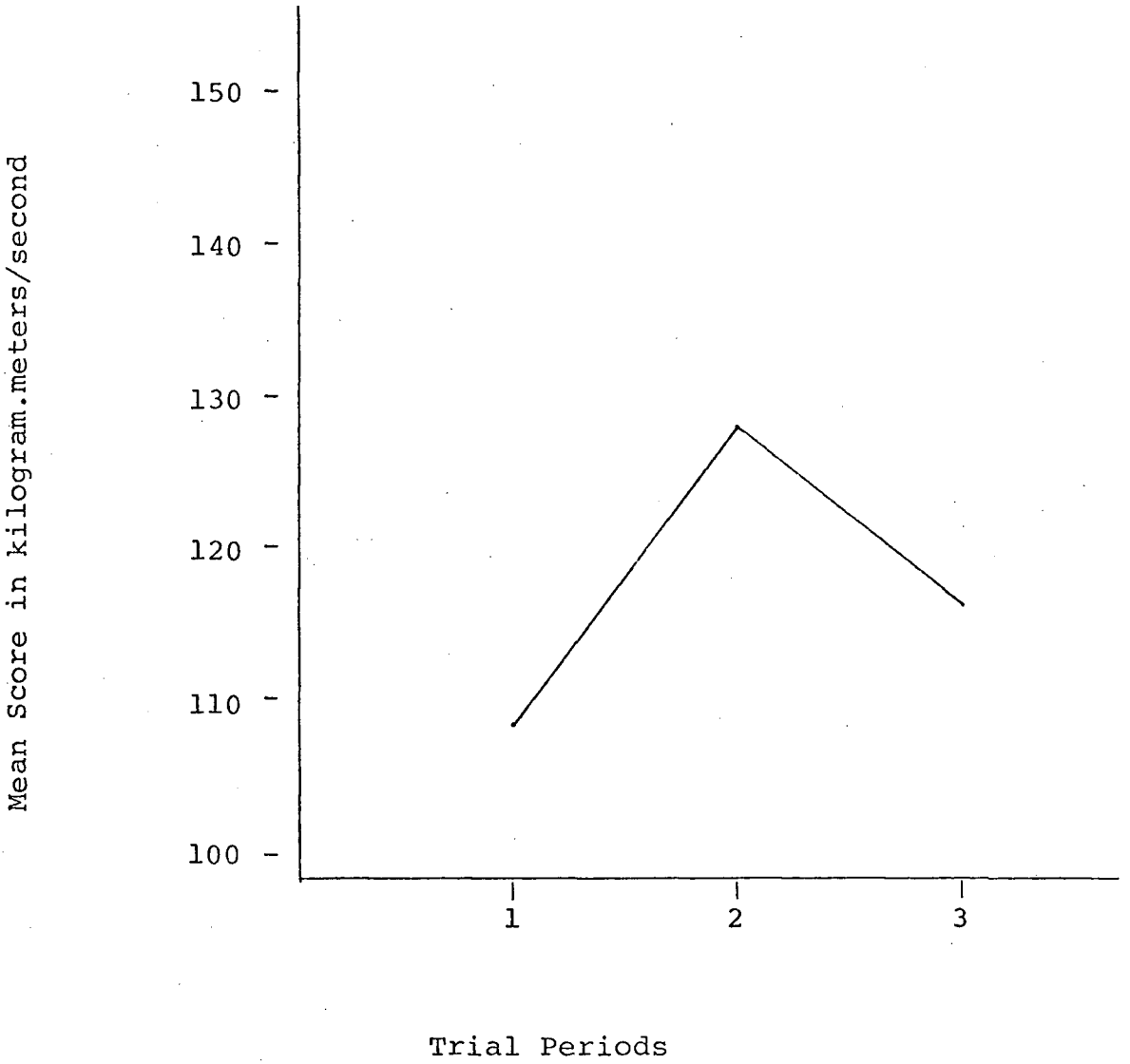

Figure 6 Mean Power Performance for the Four Treatment Conditions during Trial Periods 1, 2, and 3

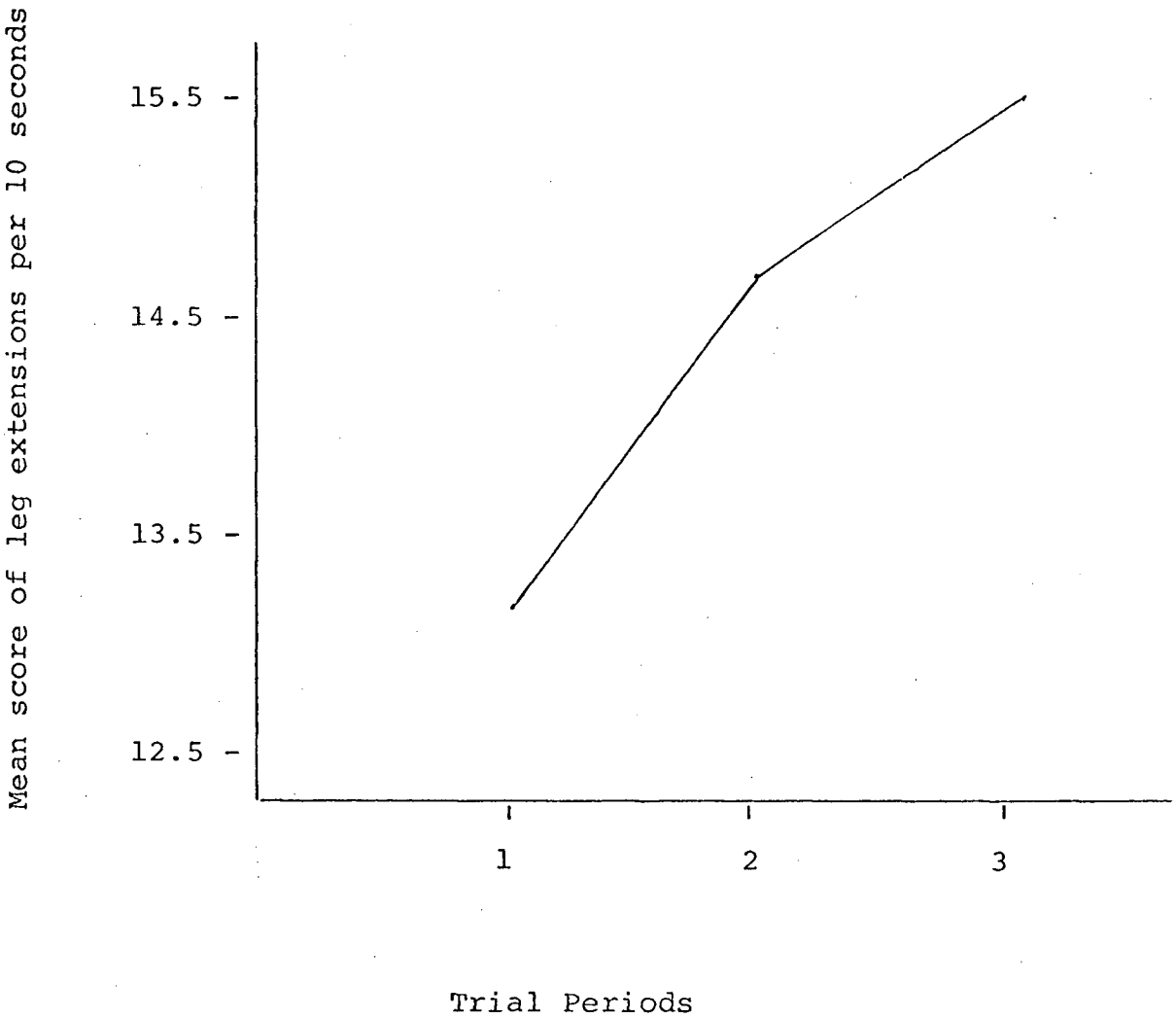

Figure 7 Mean Strength Performance on the Butkus Running Machine for the Four Treatment Conditions during Trial Periods 1, 2, and 3

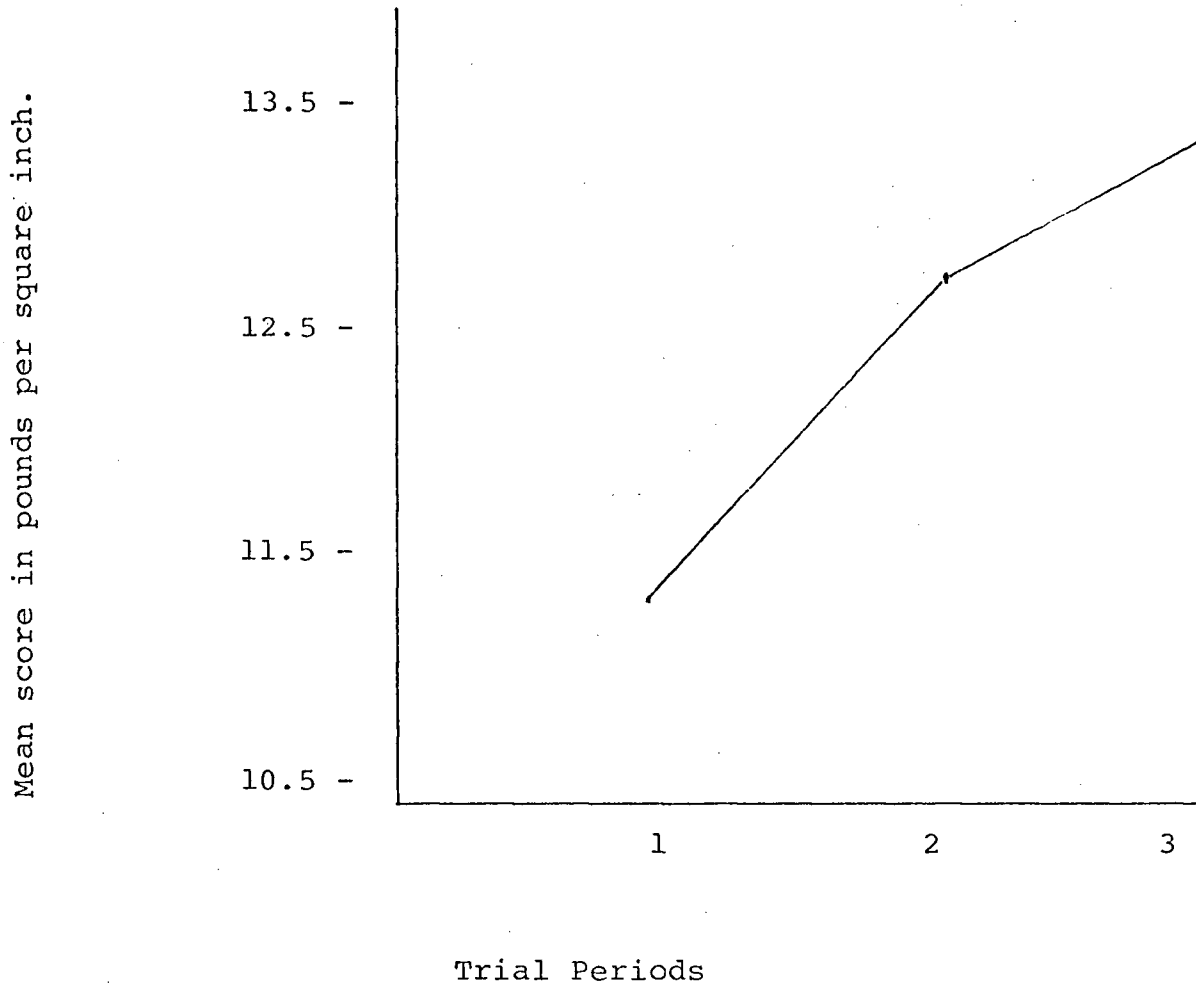

Figure 8 Mean Strength Performance on the Hydraulic Hamstring Machine for the Four Treatment Conditions during during Trial Periods 1, 2, and 3

tween correlations were not significant. When comparing the correlations between variables, from one group to another, it was shown that none of them differed significantly when using a two tailed test (Z score <2.58, p. 01) (see Appendix D).

Discussion

Before a discussion of the results of this experiment is undertaken, it is most important to discuss the major limitations of this study. The first factor limiting the degree to which one can generalize from the results to larger populations is the matter dealing with the timer recording error that occurred in Trial 3 of the 50 meter run. A malfunction of the Hunter timers occurred during the post trial period in the 50 meter run. The timers indiscriminately recorded the performance times in tenths of a second at various distances, rather than in hundredths of a second, during the 50 meter run. Not all performers, or performance times were effected. A recording error of the performances in tenths of a second occurring during the 5 meter distances of 5, 10, 15, and 20 meters, could result in an error in velocity measurement of up to 1.08 meters/second. A recording error in tenths of a second occurring during the 10 meter distances of 30, 40 and 50 meters, could result in an error in velocity measurement of up to .58 meters/second.

The effect the timer recording error had on the velocities of the effected performance times when recorded in tenths of a second meant that the performer had a faster velocity at the

effected distances. However, there was no statistical difference in the velocity curve between the treatment conditions in the 50 meter run. Therefore, the timer recording error was felt not to have negated the results of the experiment.

The second factor limiting the degree to which one can generalize from the results to larger populations is the matter dealing with the change in progressive resistance training apparatus and the type of strength tests. Initially the Universal Machine was used as both the progressive resistance training apparatus and the apparatus used to test maximal leg extension strength. Once the Universal Machine malfunctioned, during the third week of training, a change to bar bells and discs was necessitated. The same progressive resistance training procedures were followed but the testing of leg strength was done on the Nissen Leg Dynamometer, as there was not sufficient weight to test maximal leg strength in the males using free bar bells.

This change in apparatus for progressive resistance training interfered with the number of strength tests available to assess the relationship of progressive resistance training to sprinting speed. It was felt, however, that the number of tests available to assess leg strength and power were adequate for this study.

Analysis showed that there was no statistically significant difference between treatment conditions. The two Hypotheses were supported, and can be accepted on the basis

of the results. The hypotheses are:

(i) No significant difference exists between the sprint start training group, (Group III) and the progressive resistance plus sprint start training group (Group IV) in the velocity curve after a six week training period.

(ii) No significant difference exists between the control, (Group I) and the progressive resistance training group (Group II) in the velocity curve after a six week training period.

The difference in average performance for 50 meter final time for the four treatment groups, over the six week training period, provide interesting quantitative information. This information, although not statistically significant, is considered important at a coaching level and is provided in Table 7.

An average improvement of .15 seconds in the 50 meter run would be considered a significant improvement to a coach. The sprint start training group recorded an average improvement of .16 seconds. The progressive resistance training group recorded an average improvement of .13 seconds. The combination group which did both sprint start training and progressive resistance training did not improve in their average performance time for the 50 meter run as much as the other two groups. It would appear that sprint start training, or progressive resistance training done separately would produce the best results in improving the performance times over 50 meters. It was felt that of these two methods that sprint start training would be considered the most beneficial type of training

because of the larger improvement in average performance in the 50 meter run.

TABLE VII

Mean 50 Meter Final Time for Treatment Groups Obtained from The Test of Sprinting Performance for Trial Periods 1 and 3

	Group 1	Group 2	Group 3	Group 4
Trial 1	7.34	7.45	7.21	7.42
Trial 3	7.31	7.32	7.05	7.33
Difference	+.03	+.13	+.16	+.09

A degree of caution should be taken when interpreting the information on the improvement of the 50 meter final time for the four treatment groups. Due to the procedural changes and mechanical breakdowns which occurred in this experiment, it was felt that a detailed analysis of the results would be of no value. There were no statistical differences between the four treatment conditions in their performance times for the 50 meter run.

Three very important questions arise when observing the statistically significant results of this study:

(i) Why did the control group improve their sprint

performance to the same extent as the other three groups, when they did no training?

(ii) Why did the progressive resistance training group improve their performance to the same extent as the two groups that did sprint start training?

(iii) Why did the combination training group not have significantly faster sprint times than the other three groups?

The improvement of the control group in their sprint performance as much as the other three treatment conditions was interpreted as being the result of one, or a combination of factors. The first factor to be considered was the timer recording error, which could mean an improvement of performance times in the velocity curve. The second factor to be considered was that the procedural changes due to apparatus breakdown, did not allow for a large enough training effect in the other three treatment groups. Another factor that might also explain the control group's improvement in performance is that they might have participated in activities that had a positive effect on their ability to accelerate to maximum velocity, even though they were told not to change their life style over the experimental period. Two other factors that might also explain why the control group improved in their sprint performance could be that, the experiment was too brief to allow the training effect in the other three groups to become apparent, or that the basic characteristics of the sub-

jects in the control group was such that they could improve their sprint performance without the benefit of training, although this is unlikely.

The reason for the control group's improvement in their ability to accelerate to maximum velocity is unclear.

It was felt that the answers to the other two questions asked above, dealing with the 4 treatment groups lie in a mechanism limiting the rate of leg movement, which was thought to limit sprint performances. A significant trials by distance by condition interaction would be shown if the training, sprint start and progressive resistance training, done over the experimental period, was significant. In other words, because no one training procedure caused significant speed improvement, there would appear to be a mechanism limiting the rate of leg movement. This rate of leg movement theory was put forward by Slater-Hammel (1941). He found that there is a neuromuscular mechanism limiting the rate of leg movement in sprinting. The variable, rate of leg movement or strides per second, is one that track and field authorities throughout the world have accepted as being one half of a formula. This variable cannot be improved upon more than fractionally. The other half of this formula is drive, or stride length. If a sprinter were to improve his stride length and maintain his rate of leg movement, he would increase his body velocity in sprinting. This study was designed to increase the individual's lower limb strength and to assess the generality of this strength in improving drive, and thereby body velocity,

in sprinting. It would appear that to significantly improve the stride length, and thereby sprinting speed, that progressive resistance training using the Universal Machine, and barbells and discs, is not a productive method. There will be strength gains but these gains do not appear to be transferred to the significant improvement of drive, or stride length. Only productive strength sprint practises might be of value.

The results of this study although clouded with procedural and mechanical errors, has tried to clarify the effect that progressive resistance training has on the ability to accelerate to maximum velocity. Dintiman (1974), a renowned authority on improving sprint speed, stated that weight training exercises have constituted the most successful supplementary program in evaluating the strength of muscles involved in sprinting action, and ultimately in sprinting speed. The results of this study do not support Dintiman's statement.

CHAPTER V

SUMMARY AND CONCLUSIONS

Progressive resistance training for strength gains has become accepted as a logical, methodical and scientific approach. A "generality" hypothesis, stemming from progressive resistance training, has been accepted by coaches, trainers and many researchers. This hypothesis states that weight training produces strength gains, which will improve the performance in a particular skill.

Many track and field coaches throughout the world advocate progressive resistance training, using apparatus for the purpose of improving strength, which they feel will improve the athlete's ability to sprint faster. There has been a great deal of research into the degree of generality or specificity that exists between the strength gained in progressive resistance training and the effect this improved strength has on the performance of a particular skill. The literature on the effect weight training has on the speed of movement in a gross motor activity is not very clear and tends to support a "specificity" hypothesis. This hypothesis states that to improve the performance of a particular skill, practise of that skill will be the most beneficial.

Problem

This study was designed to further investigate over a six week training period, the effect progressive resistance training has on the ability to accelerate to maximum velocity, from an orthodox sprint start position.

The hypotheses under investigation were:

(i) No significant difference exists between the sprint start training group, and the progressive resistance plus sprint start training group in the velocity curve after a six week training period.

(ii) No significant difference exists between control and the progressive resistance training group in the velocity curve after a six week training period.

Limitations/Delimitations

This study was limited to the Universal Machine and barbells and discs for the progressive resistance training. A further limitation was the change from the Universal Machine to barbells and discs during the third week of progressive resistance training resulting only in measurement of maximum leg extension strength. This was measured on the Nissen Leg Dynamometer. The study was also limited by using only the 50 meter distance as a gauge for sprinting performance.

This study was also limited by the change of clock counters used to measure the performance in the Margaria Power Test for the second testing (middle) period. The change of

clock counters meant that there was no second testing period for the 50 meter run.

Subjects

Forty-one students from a university activity class in track and field volunteered as subjects.

Methods and Procedures

Each of the forty-one subjects was randomly assigned to one of four groups: control, progressive resistance training, sprint start training and combination sprint start and progressive resistance training. However, only the 32 male subject's data was statistically treated. The females were excluded because of the large inequality in number between males and females in each treatment group. Group I (control) was comprised of 10 males and 2 females; Group II (progressive resistance training) was comprised of 8 males and 3 females; Group III (sprint start training) was comprised of 10 males and 2 females; Group IV (combination progressive resistance and sprint start training) was comprised of 5 males and 1 female.

The two groups, progressive resistance and the combination group, met three times a week to weight train. The six week training period was divided into two sections of three weeks each. The first three weeks were a preparation phase consisting of relatively light loads and high repetitions and sets, i.e., 3 sets of 12 repetitions at one weight and 3 sets of 15

repetitions at a heavier weight (3 x 12 and 3 x 15). This period was to be used as an acclimatization period for the subjects, as the majority of those subjects that participated in the study had no experience with weight training. During the third week each subject had increased the weight lifted in both the 3 x 12 and 3 x 15 progressive resistance sets, by 40 pounds in the squat lift and 20 pounds in the ankle extension. The strength of the subjects had increased enough, and thereby their acclimatization to hard muscular work, to move into the second phase of the study.

It was at this time that the Universal Machine broke down and an alternate method, progressive resistance training with barbells and discs was employed. Proper technique for performing a squat lift and ankle extension with free weights was taught. Supervision of the subjects during training was undertaken to ensure that good technique was employed, to prevent injury.

The pyramid system of progressive resistance training was used in the second phase of the experiment. The pyramid system used consisted of repetitions and sets of 3 sets of 6 repetitions. Each subject was told to start with a weight that they could complete 6 repetitions such that the last 2 repetitions were quite difficult. The subjects then increased the weight for the next 6 repetitions and the last 6 repetitions, following the same procedure. To safeguard against injury, increments of only 20 pounds were used from one set to the next.

The progressive resistance training and combination group did their training independently so that the performance for the subjects in each group would not have a detrimental influence on each other. The sprint start and combination training groups did not do their sprint training together for the same reason.

The subjects involved in sprint start training met three times per week and accelerated a distance of 50 meters for each trial. Each subject performed a total of 20 trials per session. Enough rest, 15 minutes, was given to ensure reliability of performance. Each individual was urged to make each trial a maximum. The following variables in the set position were controlled during each trial run for each individual:

(i) Hand-to-hand distance (laterally). Each individual had the distance measured for them. This marked distance was placed on the ground. It was the distance between thumbs when the arms were directly under the shoulders.

(ii) A 90° angle between trunk and arms taken on the midline of the arms and trunk.

(iii) The toe-to-toe longitudinal spacing of 16 inches for each individual.

(iv) Front knee joint angle of 90°.

(v) Rear leg knee joint angle of 120°.

Both rear and front leg knee joint angles were taken on the midline of the upper and lower leg. Each subject assumed the set position when they were ready. The measurements of the angles at both knees and at the shoulders were taken. The subject was given the command "good" if all angles were all right, i.e., front knee at 90°, rear knee at 120° and trunk at 90°. If the subject did not assume the desired position he was given verbal cues such as "up, forward, down, back," etc. to assist in assuming the proper position. Once the subject had assumed this position he held the position for practise purposes to acquire a feel for the various positions of the front and rear legs and trunk. He then went down to the on your marks position to rest his fingers, and when ready he assumed the get set position again. If the angles at the knees and shoulders were correct he initiated running on his own response. This procedure worked very well. It was found that after the second week of training, the subjects assumed the set position with very few adjustments of body angles.

Three testing periods measured the following parameters of strength, power and speed:

(i) Acceleration and velocity maintenance time in running 50 meters, with times taken at 5, 10, 15, 20, 30, 40 and 50 meters.

(ii) Maximum anaerobic power as measured by the Margaria Power Test.

(iii) Maximal hamstring strength as measured on the Hy-

draulic Machine during a 10 second interval.

(iv) Maximum leg extension strength as measured in a one maximum repetition on the Nissen Leg Dynamometer.

(v) Maximum number of leg extensions and flexions during a 10 second trial on the Butkus Running Machine.

Testing for the sprint performances occurred at the beginning of the experimental period and at the end, i.e., (first week and seventh week). The subjects were tested one week after the training had ceased (seventh week) to allow them to recover from the fatiguing effects of training. The Nissen Leg Dynamometer Test for leg extension strength was done at the end of the third and seventh week. The rest of the tests, Margaria Power Test, Hamstring Strength Test and Running Machine Test, were done three times during the experimental period: during the first week, at the end of the third week and at the end of the seventh week.

Analysis of Data

The data was analyzed with a two way ANOVA to test the effects of the exercise treatment over the six week training period. These calculations were carried out by a UBC computer program, BMD P2V, which provided a repeated measures analysis of variance, with an orthogonal breakdown of each source of variation to test for trend. The data was also subjected to an analysis of correlation coefficients, to test for the

relationship among the exercise treatments. The UBC computer program UBC SIMCORT was used in this procedure.

Results and Discussion

Analysis of variance yielded no statistically significant difference between the various treatment conditions in sprinting performance. No one treatment group improved more than the other. All four treatment conditions significantly improved their sprinting performance.

The analysis of variance done on the strength and power measures yielded significant strength improvement on the strength tests: Leg Dynamometer, Running Machine and Hamstring Machine, and significant power improvement on the Margaria Power Test. A significant improvement in performance occurred over the six week training period for all four treatment groups. All of these strength and power relationships are expressed graphically in Figures 5 to 8.

The major limitations of this study which limit the degree to which one can generalize from the results to larger populations are, the timer recording error, the change in progressive resistance training apparatus, and the type of strength tests.

The malfunction of the Hunter timers occurred during the post trial period in the 50 meter run. The timers indiscriminately recorded the performance times in tenths of a second at various distances rather than in hundredths of a second, during the 50 meter run. Not all performers, or

performance times were effected. The effect the timer recording error had on the velocities of the effected performance times when recorded in tenths of a second meant that the performer had a faster velocity at the effected distances. However, there was no statistical difference in the velocity curve between the treatment conditions in the 50 meter run. Therefore, the timer recording error was felt not to have negated the results of the experiment.

Initially the Universal Machine was used as both the progressive resistance training apparatus and the apparatus used to test maximal leg extension strength. Once the Universal Machine malfunctioned, during the third week of training, a change to barbells and discs was necessitated. The same progressive resistance training procedures were followed but the testing of leg strength was done on the Nissen Leg Dynamometer, as there was not sufficient weight to test maximal leg strength in the males using free barbells. The change in apparatus for progressive resistance training interfered with the number of strength tests available to assess the relationship of progressive resistance training to sprinting speed. It was felt, however, that the number of tests available to assess leg strength and power were adequate for this study.

The differences between the 50 meter final times for the four treatment groups were not significantly different. However, these differences could be important on a coaching level. The sprint start training group recorded an average

improvement of .16 seconds, and the progressive resistance training group recorded an average improvement of .13 seconds in the 50 meter final time. This improvement in sprinting performance over a relatively short training period of time could be meaningful to a coach. However, a degree of caution should be taken when interpreting the information on the improvement of the 50 meter final time for the four treatment groups. Due to the procedural changes and mechanical breakdowns which occurred in this experiment, it was felt that a detailed analysis of the results would be of no value. There were no statistical differences between the four treatment conditions in their performance times for the 50 meter run.

Conclusions

On the basis of the results obtained in this study, the two hypotheses are accepted:

(i) No significant difference exists between the sprint start training group, and the progressive resistance plus sprint start training group in the velocity curve after a six week training period.

(ii) No significant difference exists between control and the progressive resistance training group in the velocity curve after a six week training period.

Many national and international coaches and researchers Marlow (1967), Marlow and Watts (1970), Dintiman (1971), and Paish (1976) advocate progressive resistance training using

Universal Machines or barbells and discs, in a supplementary program to sprint training. The results of this study question this practise.

The results of this study tend to support those researchers who found no improvement in sprinting performance with the use of a supplementary program of progressive resistance training. However, the inconsistency between the results and conclusions of this study, and other similar studies that found a significant improvement in sprinting performance through the use of a supplementary program of progressive resistance training, indicate that there is a great deal yet to be learned about this relationship. The mechanism limiting the rate of leg movement, theorized by Slater-Hammel (1941), may in some way limit the application of strength gains to sprinting performance. Experiments that deal with more specific types of strength training to the art of sprinting, and experiments that investigate the mechanism limiting the rate of leg movement are needed.

REFERENCES

Bachman, J. C. "Specificity vs. Generality in Learning and Performing Two Large Muscle Motor Tasks," Research Quarterly. 32:3-11, 1961.

Barnes, R. "The Effect of Weight Training on Speed in the 100 Yard Dash." Unpublished Master's Thesis, Arkansas State College, 1961.

Bates, J. "The Effect of Static and Dynamic Strength Training and Position of Exercise on the Acquisition of Strength, Speed of Movement, Reaction Time and Endurance." Unpublished Doctoral Thesis, Louisiana State University, 1967.

Berger, R. A. "Effect of Varied Weight Training Programs on Strength," Research Quarterly. 33:168-181, 1962.

_____. "Effects of Dynamic and Static Training on Vertical Jumping Ability," Research Quarterly. 34:419-424, 1962.

_____. "Comparison Between Resistance Load and Strength Improvement," Research Quarterly. 33:637, 1963.

_____. "Comparison of the Effect of Various Weight Training Loads on Strength," Research Quarterly. 36:141-146, 1965.

_____. and Blaschke, L. A. "Comparison of Relationships between Motor Ability and Static and Dynamic Strength," Research Quarterly. 38:144-146, 1966.

Berger, R. A. and Hardage, B. "Effect of Maximum Loads for Each of Ten Repetitions on Strength Improvement," Research Quarterly. 38:715-718, 1967.

Bergeron, P. "The Effects of Static Strength Training at Various Positions and Dynamic Strength Training Through a Full Range of Motion on Strength, Speed of Movement and Power." Unpublished Doctoral Thesis, Louisiana State University, 1966.

Blucker, J. A. "A Study of the Effects of Leg Strengthening Exercises on the Vertical Jumping and Speed of Running of College Women." Unpublished Master's Thesis, University of North Carolina, 1965.

Boarman, M. "The Effects of Strength Training on Speed of Movement." Unpublished Master's Thesis, Pennsylvania State University, 1967.

Capen, E. K. "Effect of Systematic Weight Training on Power, Strength and Endurance," Research Quarterly. 21:83-93, 1950.

Chui, E. F. "The Effect of Systematic Weight Training on Athletic Power," Research Quarterly. 21:188-194, 1950.

_____. "Effects of Isometric and Dynamic Weight Training Exercises Upon Strength and Speed of Movement," Research Quarterly. 35:246-257, 1964.

Clarke, H. H. Application of Measurement to Health and Physical Education. New Jersey: Prentice Hall Inc., 1950.

Clarke, D. H. and Henry, F. M. "Neuromotor Specificity and Increased Speed from Strength Development," Research Quarterly. 32:315-325, 1961.

Colgate, J. A. "Arm Strength Relative to Arm Speed," Research Quarterly. 37:14-22, 1966.

Costill, D. L., Miller, S. J., Meyers, W. C., Keltoe, F. M. and Hoffman, W. M. "Relationship Among Selected Tasks of Explosive Leg Strength and Power," Research Quarterly. 37:785-787, 1968.

Cummings, G. C. "The Effect of Weight Training on the Speed of Running." Unpublished Master's Thesis, University of California, 1965.

Delorme, T. L. "Heavy Resistance Exercises," Archives of Physical Medicine. 607-630, 1946.

Dickinson, H. D. "The Effect of Foot Spacing on the Starting Time and Speed in Sprinting and the Relationship Between the Size of the Man and Position of the Feet." Unpublished Master's Thesis, University of Iowa, 1934.

Dintiman, G.B. "Effects of Various Training Programs in Running Speed," Research Quarterly. 35:456-463, 1965.

_____. Sprinting Speed: Its Improvement for Major Sports Competition. Springfield: Charles C. Thomas, 1971.

_____. What Research Tells the Coach About Sprinting. Washington: American Alliance for Health, Physical Education and Recreation, 1974.

Dyson, G. The Mechanics of Athletics. London: University of London Press, 1973.

Ferguson, G. Statistical Analysis in Psychology and Education. New York: McGraw Hill Book Company, 1971.

Fishbain, J. "The Effects of a Nine Week Training Program Upon Measures of Dynamic Strength of Adolescent Males." Unpublished Master's Thesis, University of Wisconsin, 1961.

Hayden, T. C. and Walker, G. H. "A Comparison of the Starting Time of Runners Using Holes in Track and Starting Blocks," Research Quarterly. IV:117-123, 1933.

Hellixon, P. "The Effects of Progressive Heavy Resistance Exercises Using Near Maximum Weight on the Running and Jumping Ability of the First Year High School Track Performances." Unpublished Master's Thesis, University of Wisconsin, 1961.

Henry, F. M. "Force-Time Characteristics of the Sprint Start," Research Quarterly. 17:301-318, 1952.

_____ and Nelson, L. A. "Age Differences and Inter-Relationships Between Skill and Learning in Gross Motor Performance of Ten and Fifteen Year Old Boys," Research Quarterly. 27:162-175, 1956.

_____ and Trafton, T. R. "The Velocity Curve of Sprint Running," Research Quarterly. 14:409-422, 1951.

_____ and Whitley, J. D. "Relationships Between Individual Differences in Strength, Speed and Mass in Arm Movements," Research Quarterly. 31:24-33, 1959.

Houts, L. J., Parrish, A. M. and Hallebrandt, F. A. "The Influence of Heavy Resistance Exercise on Strength," The Physiotherapy Review. XXVI:299-304, 1946.

Jackson, A. S. and Baumgartner, T. A. "Measurement Schedules of Sprint Running," Research Quarterly. 40:708-711, 1969.

_____ and Cooper, J. M. "Effect of Hand Spacing and Rear Knee Angle in the Sprinters Start," Research Quarterly. 41:378-382, 1971.

Kistler, J. W. "A Study of the Distribution of the Force Exerted Upon the Blocks in Starting the Sprint from Various Starting Positions." Unpublished Master's Thesis, University of Iowa, 1934.

Kusinitz, I. and Keeney, C. E. "Effects of Progressive Weight Training on Health and Physical Fitness of Adolescent Boys," Research Quarterly. 29:294-301, 1958.

Laycoe, R. R. and Marteniuk, R. G. "Learning and Tension as Factors in Static Strength Gains Produced by Static and Eccentric Training," Research Quarterly. 42:299-306, 1971.

Lotter, W. S. "Interrelationships Among Reaction Times and Speed of Movement in Different Limbs," Research Quarterly. 31:147-155, 1960.

Margaria, R. Aghemo, P. E. and Ravelli, E. "Measurement of Muscular Power (Anaerobic) in Man," Journal of Applied Physiology. 21:1662-1664, 1968.

Marlow, B. Sprinting and Relay Racing. London: Amateur Athletic Association, 1967.

_____ and Watts, D. Track Athletics. London: Pelham Books Ltd., 1970.

Masley, J. W., Hairabedon, A. and Donaldson, W. D. "Weight Training in Relation to Strength, Speed and Coordination," Research Quarterly. 24:309-315, 1953.

Meisel, G. S. "Effects of Weight Training on Speed of Running." Unpublished Master's Thesis, Pennsylvania State University, 1957.

Mendryk, F. "Effects of Isometric, Isotonic and Speed Conditioning Programs on Speed of Movement, Reaction Time and Strength of College Men." Unpublished Doctoral Thesis, University of Alberta, 1966.

Menly, R. C. and Rosemier, R. A. "Effectiveness of Four Track Starting Positions on Acceleration," Research Quarterly. 55:378-382, 1968.

Morant, C. "A Comparison of Exer-Genic, Isometric and Isotonic Training Programs on Selected Components of Motor Ability." Unpublished Doctoral Thesis, Florida State University, 1970.

Morehouse, L. E. and Cooper, J. M. Kinesiology. New Jersey: Prentice Hall, 1967.

O'Shea, J. P. "Effects of Varied, Short Term Weight Training Programs on Improving Performances in the 400 Meter Run," Research Quarterly. 40:248-250, 1968.

Oxendine, J. B. "Generality and Specificity in the Learning of Fine and Gross Motor Skills," Research Quarterly. 38:87-94, 1966.

Pierson, W. R. and Rasch, P. J. "Strength and Speed," Perceptual and Motor Skills. 14:144, 1962.

Pipes, T. V. and Wilmore, J. H. "Isokinetic Versus Isotonic Strength Training in Adult Men," Medicine and Science in Sports. 7:262-274, 1975.

Rasch, P. J. "Relationship of Arm Strength, Weight and Length to Speed of Arm Movement," Research Quarterly. 28:328-332, 1954.

Robichaux, W. A. "Relationship Between Demonstrated Skill in Performing Sports Activities and Learning New Gross Motor Skill." Unpublished Doctoral Thesis, University of Southern California, 1960.

Rodgers, K. L. and Berger, R. A. "Motor Unit Involvement and Tension During Maximum Voluntary Concentric, Eccentric and Isometric Contractions of the Elbow Flexors," Medicine and Science in Sports. 6:253-259, 1974.

Schultz, G. W. "The Effects of Direct Practice Repetitive Sprinting and Weight Training on Selected Motor Performance Tests," Research Quarterly. 30:108-118, 1967.

Smith, L. E. "Specificity of Individual Differences of Relationships Between Forearm Strength and Speed of Forearm Flexion," Research Quarterly. 40:191-197, 1969.

Stock, M. "Influence of Various Track Starting Positions on Speed," Research Quarterly. 33:607-614, 1962.

Sweeting, R. L. "Effects of Various Running and Weight Training Programs on Sprinting Speed." Unpublished Master's Thesis, Pennsylvania State University, 1963.

Walker, G. A. and Hayden, T. C. "The Optimum Time for Holding a Sprinter Between the Set and the Stimulus (Gunshot)," Research Quarterly. 4:124-130, 1933.

Whitley, J. D. and Smith, L. E. "Velocity Curves and Static Strength-Action Strength Correlations in Relation to the Mass Moved by the Arm," Research Quarterly. 34:379-395, 1963.

_____ and Smith, L. E. "Influence of Three Different Training Programs on Strength and Speed of a Limb Movement," Research Quarterly. 37:132, 142, 1965.

Wilkin, B. M. "The Effect of Weight Training on Speed of Movement," Research Quarterly. 23:361-369, 1952.

Winningham, S. N. "Effect of Training with Ankle Weights on Running Skill." Unpublished Doctoral Thesis, University of Southern California, 1965.

Woodall, T. "Weight Training of the Arms and Upper Body and Its Effect Upon Speed of High School Boys in the 100 Yard Dash." Unpublished Master's Thesis, Colorado State College, 1960.

Zorbas, W. "The Effect of Weight Lifting Upon the Speed of Muscular Contractions." Unpublished Master's Thesis, Springfield College, 1950.

APPENDIX A

INTRODUCTION TO STUDENTS

Appendix A

Instructions for Testing Procedures

1. Rest for 15 minutes in a supine position.
2. Weigh in.
3. Warm-up 10 minutes of jogging and stretching.
   Sprints - 5 accelerations of 60 meters with a walk back. The speeds of each succeeding acceleration was to increase, until the sixth acceleration, which was to be of a maximum effort.
   Progressive resistance - 2 sets of 4 repetitions with one half body as resistance.
4. Five to eight minute rest.
5. <u>Testing Order</u>
   A. Margaria Power Test - 3 all out trials resting 10 minutes between trials.
      Rest 10 minutes.
   B. Sprints - 3 all out sprints from a standard start position resting 10 minutes between each trial.
      Rest 10 minutes.
   C. Running Machine - 3 all out trials resting 10 minutes between trials.
      Rest 15 minutes.
   D. Leg Extension Strength
      Universal machine and Nissen Leg dynamometer - 1 maximal repetition.

APPENDIX B

RAW SCORES

RAW SCORES

FOR SPRINTING PERFORMANCE

TRIAL 1

Subject Group 1	Sprinting Distances Measured in Meters Per Second								
	5 m.	10 m.	15 m.	20 m.	30 m.	40 m.	50 m.	Ave. Vel.	50m. Time
1	3.52	6.94	7.35	7.81	8.06	7.87	7.41	6.82	7.33
2	3.40	6.58	7.25	7.58	7.87	7.94	8.20	6.35	7.88
3	3.33	6.25	6.67	7.46	7.46	7.41	6.80	7.26	6.89
4	3.70	7.14	7.69	7.94	8.47	8.55	8.26	6.96	7.18
5	3.47	6.85	7.46	8.33	8.06	8.20	7.81	6.85	7.30
6	3.73	6.76	7.25	6.94	7.94	8.06	7.63	6.73	7.43
7	3.23	6.49	7.14	7.81	7.94	8.06	7.87	6.28	7.96
8	3.05	6.58	6.49	7.04	7.41	7.30	7.35	7.00	7.14
9	3.70	6.94	7.46	7.58	8.77	8.70	7.87	7.18	6.96
Subject Group 11									
13	3.45	7.04	7.25	7.94	8.77	8.06	7.35	6.96	7.18
14	3.33	6.58	6.85	7.25	7.75	7.81	7.58	6.61	7.57
15	3.52	6.85	7.35	7.69	8.20	7.75	7.87	6.89	7.26
16	3.55	6.67	7.46	7.69	8.00	7.87	7.69	6.85	7.30
17	3.38	6.76	7.25	7.81	7.94	7.81	7.30	6.70	7.46
18	3.65	7.25	7.69	8.06	8.62	8.33	8.13	7.23	6.92
19	3.57	6.94	7.14	7.46	8.26	8.40	8.00	7.04	7.10
20	2.98	5.38	6.49	6.49	6.54	6.49	6.37	5.69	8.79

Subject Group 111	5 m.	10 m.	15 m.	20 m.	30 m.	40 m.	50 m.	Ave. Vel.	50m. Time
24	3.42	6.76	7.14	7.69	7.81	8.06	7.25	6.72	7.44
25	3.76	6.85	7.25	7.46	8.70	8.06	7.81	7.05	7.09
26	3.40	7.04	7.25	7.25	8.26	8.00	7.63	6.82	7.33
27	3.38	6.85	7.14	7.69	7.81	7.81	7.46	6.70	7.46
28	3.91	7.46	7.81	8.47	8.93	8.77	8.70	7.59	6.59
29	3.57	6.94	7.69	7.58	8.00	7.75	7.35	6.82	7.33
30	3.73	6.94	7.25	8.33	8.26	8.20	7.87	7.09	7.05
31	3.70	6.49	7.46	8.20	8.13	7.75	7.69	6.93	7.22
32	3.29	6.85	7.25	7.94	7.75	7.46	7.35	6.61	7.56
33	3.45	7.35	7.58	7.94	8.20	8.40	7.81	7.11	7.03
Subject Group 1V									
36	3.52	6.58	7.69	7.69	7.87	7.87	7.69	6.83	7.32
37	3.57	7.14	7.35	7.69	7.94	8.55	8.26	6.97	7.17
38	3.52	6.58	7.58	7.25	7.69	7.58	7.41	6.67	7.50
39	3.52	6.94	7.25	8.06	8.20	7.87	8.20	6.98	7.16
40	3.18	6.76	6.76	6.58	7.19	7.41	7.25	6.32	7.91

RAW SCORES

FOR SPRINTING PERFORMANCE

TRIAL 3

Subject Group 1	Sprinting Distances Measured in Meters Per Second								
	5 m.	10 m.	15 m.	20 m.	30 m.	40 m.	50 m.	Ave. Vel.	50m. Time
1	3.38	6.59	7.14	8.06	8.33	8.33	7.58	6.89	7.26
2	3.57	6.25	7.14	8.33	8.33	8.33	7.69	6.94	7.20
3	3.47	6.41	7.04	7.35	7.69	7.58	7.19	6.56	7.62
4	3.57	8.33	8.33	7.69	8.33	8.33	8.33	7.25	6.90
5	3.50	6.76	6.58	7.69	8.20	8.47	7.25	6.79	7.36
6	3.47	6.49	6.94	7.58	7.81	7.94	7.46	6.73	7.43
7	3.65	6.25	7.35	7.94	8.13	8.47	8.33	7.04	7.10
8	3.31	5.59	7.04	7.14	7.81	7.75	7.29	6.49	7.70
9	3.79	6.67	7.58	7.69	8.55	7.87	7.87	7.05	7.09
Subject Group 11									
13	3.57	8.33	8.33	8.33	7.69	8.33	8.33	7.25	6.90
14	3.33	7.14	7.14	7.14	7.69	7.70	7.69	6.67	7.50
15	3.57	8.33	8.33	7.14	8.33	7.70	8.33	7.14	7.00
16	3.85	6.94	7.25	7.46	8.00	7.75	7.87	6.91	7.24
17	3.60	6.10	6.94	7.04	7.25	7.94	7.63	6.59	7.59
18	3.57	8.33	8.33	8.33	8.33	8.33	7.69	7.25	6.90
19	3.76	6.58	7.14	8.33	8.40	8.33	8.33	7.19	6.95
20	2.96	5.75	6.67	6.58	7.04	6.99	6.49	5.92	8.45

Subject Group 111	5 m.	10 m.	15 m.	20 m.	30 m.	40 m.	50 m.	Ave. Vel.	50m. Time
24	3.42	6.94	6.94	7.81	8.13	7.35	7.52	6.70	7.46
25	3.97	6.67	7.35	7.69	8.40	8.55	7.87	7.17	6.97
26	3.85	8.33	8.33	7.14	7.69	7.69	7.69	7.04	7.10
27	3.85	7.14	7.14	7.14	8.33	8.33	7.69	7.04	7.10
28	3.85	8.33	8.33	8.33	9.10	8.33	9.10	7.69	6.50
29	3.94	6.41	7.58	7.46	8.20	7.52	7.81	6.93	7.21
30	3.94	6.85	6.58	8.47	8.47	9.80	8.06	7.36	6.79
31	3.82	6.41	7.58	8.20	8.47	8.47	7.94	7.16	6.98
32	3.33	7.14	7.14	8.33	7.14	8.33	7.14	6.58	7.60
33	3.57	7.14	8.33	8.33	9.10	8.33	8.33	7.35	6.80
Subject Group 1V									
36	3.36	6.17	7.25	7.14	7.63	7.58	7.46	7.53	7.66
37	3.57	8.33	7.14	7.14	8.33	8.33	8.33	7.14	7.00
38	3.57	7.14	7.14	7.14	8.33	7.69	7.14	6.76	7.40
39	3.85	7.14	7.14	7.14	8.33	8.33	8.33	7.14	7.00
40	3.55	5.95	6.85	7.69	7.63	7.58	7.35	6.57	7.61

RAW SCORES
FOR NISSEN LEG DYNAMOMOTER TEST
(MEASURED IN POUNDS PULL)

Subject Group 1	Trial Periods	
	Trial 2	Trial 3
1	1600	1510
2	1020	940
3	1870	2230
4	1190	1210
5	900	1140
6	530	740
7	900	970
8	1150	1300
9	880	1000
10	980	920
Subject Group 11		
13	630	880
14	680	850
15	1320	1350
16	1080	1100
17	1350	1670
18	840	900
19	1070	1380
20	560	560

Subject Group 111		
24	1350	1180
25	1060	930
26	760	1120
27	750	800
28	1020	1110
29	1180	1150
30	1310	1110
31	850	920
32	940	1130
33	990	1290
Subject Group 1V		
36	1140	1430
37	1110	1230
38	800	980
39	1070	890
40	1370	1300

RAW SCORES

FOR MARGARIA POWER TEST

(MEASURED IN KILOGRAM.M/SEC.)

Subject Group I	Trial 1	Trial 2	Trial 3
1	122.05	116.32	104.23
2	121.95	127.45	121.95
3	128.86	142.23	133.64
4	93.27	97.55	91.45
5	134.45	149.05	131.32
6	121.91	150.55	124.36
7	99.27	99.27	103.73
8	133.36	130.10	127.64
9	105.00	107.77	109.86
10	102.68	135.73	84.05
Subject Group II			
13	130.09	133.36	133.36
14	97.18	99.27	82.73
15	129.36	144.55	120.68
16	111.24	146.36	122.23
17	116.00	125.41	122.86
18	118.55	121.45	124.36
19	116.59	119.32	108.41
20	70.83	75.50	75.50

Subject Group 111			
24	115.59	117.82	143.73
25	100.86	100.86	109.86
26	122.23	122.23	111.77
27	122.23	117.00	122.23
28	117.05	119.95	117.05
29	117.09	135.50	131.77
30	146.36	163.86	142.41
31	111.14	103.64	113.86
32	92.95	103.36	96.86
33	112.73	107.68	109.86
Subject Group 1V			
36	123.95	118.95	118.95
37	109.18	116.91	114.41
38	155.59	163.23	159.41
39	99.45	113.36	118.91
40	130.45	155.64	145.36

RAW SCORES
FOR MARGARIA POWER TEST
(VELOCITY) (MEASURED IN M/SEC.)

Subject Group 1	Trial Periods		
	Trial 1	Trial 2	Trial 3
1	1.71	1.63	1.46
2	1.56	1.63	1.56
3	1.35	1.49	1.40
4	1.52	1.59	1.49
5	1.75	1.94	1.71
6	1.49	1.84	1.52
7	1.56	1.56	1.63
8	1.63	1.59	1.56
9	1.52	1.56	1.59
10	1.43	1.89	1.17
Subject Group 11			
13	1.59	1.63	1.63
14	1.37	1.56	1.30
15	1.79	2.00	1.67
16	1.52	2.00	1.67
17	1.35	1.46	1.43
18	1.63	1.67	1.71
19	1.71	1.75	1.59
20	1.06	1.13	1.13

Subject Group 111			
24	1.56	1.59	1.94
25	1.46	1.46	1.59
26	1.63	1.63	1.49
27	1.63	1.56	1.63
28	1.63	1.67	1.63
29	1.59	1.84	1.79
30	1.84	2.06	1.79
31	1.63	1.52	1.67
32	1.43	1.59	1.49
33	1.56	1.49	1.52
Subject Group 1V			
36	1.49	1.43	1.43
37	1.56	1.67	1.63
38	1.63	1.71	1.67
39	1.43	1.63	1.71
40	1.40	1.67	1.56

RAW SCORES

FOR BUTKUS RUNNING MACHINE TEST

(MEASURED IN LEG EXTENSIONS PER 10 SECONDS)

Subject Group 1	Trial Periods		
	Trial 1	Trial 2	Trial 3
1	15	16	15
2	15	17	20
3	14	17	17
4	9	12	15
5	14	14	16
6	12	12	13
7	12	13	15
8	14	15	16
9	9	16	14
10	14	13	11
Subject Group 11			
13	14	17	18
14	14	15	15
15	12	15	18
16	12	17	15
17	14	16	17
18	14	16	16
19	15	15	14
20	10	13	13

Subject Group 111			
24	9	12	12
25	15	14	15
26	14	13	15
27	12	16	18
28	14	18	17
29	15	13	14
30	15	17	15
31	12	12	13
32	15	12	14
33	14	15	17
Subject Group 1V			
36	12	16	17
37	14	14	14
38	15	15	15
39	13	18	17
40	13	13	13

RAW SCORES
FOR HYDRAULIC HAMSTRING MACHINE TEST
(MEASURED IN POUNDS PER SQUARE INCH)

Subject Group 1	Trial Periods		
	Trial 1	Trial 2	Trial 3
1	12	12	13
2	11	12	13
3	9	13	13
4	11	12	12
5	12	12	13
6	10	13	12
7	11	12	12
8	11	13	13
9	12	13	12
10	11	12	12
Subject Group 11			
13	11	12	13
14	12	13	13
15	11	13	13
16	12	13	14
17	12	13	13
18	12	13	13
19	13	13	13
20	11	11	11

Subject Group 111			
24	11	13	13
25	12	12	13
26	11	12	13
27	11	13	13
28	12	13	13
29	13	14	14
30	11	13	13
31	10	13	13
32	9	10	11
33	12	13	13
Subject Group 1V			
36	11	13	13
37	12	12	13
38	12	13	13
39	12	13	13
40	11	12	13

APPENDIX C

ANALYSIS OF VARIANCE TABLES

Analysis of Variance for Sprinting Performance

Source	df	MS	F	P
Condition	3	.12	.87	.47
Error	29	.14		
Trial	1	.07	9.20	<.01
Trial X Condition	3	.01	1.21	.32
Error	29	.01		
Distance	7	304.29	1008.36	<.01
Distance X Condition	21	.02	.92	.57
Error	203	.03		
Trial X Distance	7	.02	.44	.88
Trial X Distance X Condition	21	.00	.96	.52
Error	203	.003		

$F_{.01;\ 1,29} = 7.60$

$F_{.01;\ 7,203} = 2.73$

Analysis of Variance For Nissen Leg Dynamomoter Test

Source	df	MS	F	P
Condition	3	71019.31	.41	.75
Error	29	175035.13		
Trial	1	123428.63	8.90	.01
Trial X Condition	6	6744.94	.49	.70
Error	29	13874.62		

$F_{.01;\ 1,29} = 7.60$

Trend Analysis For Margaria Power, Margaria Velocity, Hamstring Machine, and Running Machine Tests

Margaria Power Test	MS	F	P
Linear	458.13	2.18	.15
Stairs X Condition	372.82	1.78	.18
Error	210.50		
Quadratic	4908.96	12.06	<.01
Stairs X Condition	590.91	1.45	.25
Error	407.08		

F.01; 1,29 = 7.60

Margaria Velocity Test	MS	F	P
Linear	.05	1.95	.17
Stairs X Condition	.004	.15	.93
Error	.03		
Quadratic	.22	11.58	<.01
Stairs X Condition	.04	2.05	.13
Error	.02		

F.01; 1,29 = 7.60

Hydraulic Hamstring Machine Test	MS	F	P
Linear	30.13	86.63	<.01
Trial X Condition	.33	.96	.40
Error	.35		
Quadratic	4.40	16.24	<.01
Trial X Condition	.10	.37	.78
Error	.27		

F.01; 1,29 = 7.60

Analysis of Variance For Margaria Power Tests

Source	df	MS	F	P
Condition	3	3725.10	1402.36	.49
Error	29	4547.98		
Trial	2	12683.54	8.69	<.01
Trial X Condition	6	481.86	1.56	.18
Error	58	308.79		

F.01; 2,58 = 4.98

Analysis of Variance For Margaria Power Tests
(Velocity)

Source	df	MS	F	P
Condition	3	.04	.56	.65
Error	29	.07		
Trial	2	.13	6.10	<.01
Trial X Condition	6	.02	.97	.45
Error	58	.02		

F.01; 2,58 = 4.98

Analysis of Variance For Butkus Running Machine Test

Source	df	MS	F	P
Condition	3	2.00	.28	.84
Error	29	7.07		
Trial	2	36.32	16.74	<.01
Trial X Condition	6	1.19	.55	.77
Error	58	2.18		

F.01; 2,58 = 4.98

Analysis of Variance For Hydraulic Hamstring Machine Test

Source	df	MS	F	P
Condition	3	.86	.67	.58
Error	29	1.28		
Trial	2	17.27	55.8	.01
Trial X Condition	6	.21	.70	.65
Error	58	.31		

$F_{.01;\ 2,58} = 4.98$

Trend Analysis For Sprinting Performance

Distance	MS	F	P
Linear	77.67	10756.63	
Distance X Condition	.03	.04	.60
Error	.07		
Quadratic	825.56	11242.37	
Distance X Condition	.07	.97	.42
Error	.07		
Cubic	245.20	10634.31	
Distance X Condition	.02	.94	.43
Error	.02		

F.01; 1,29 = 7.60

Trend Analysis For Sprinting Performance

Trial X Distance	MS	F	P
Linear			
Trial X Distance	.01	1.86	.18
Trial X Distance X Condition	.01	.75	.53
Error	.01		
Quadratic			
Trial X Distance	.08	12.48	.01
Trial X Distance X Condition	.01	1.57	.22
Error	.01		
Cubic			
Trial X Distance	.004	1.47	.24
Trial X Distance X Condition	.002	.74	.54
Error	.003		

F.01; 1,29 = 7.60

Butkus Running Machine Test	MS	F	P
Linear	66.00	23.40	.01
Time X Condition	1.19	.40	.74
Error	2.84		
Quadratic	6.64	4.37	.05
Time X Condition	1.19	.78	.51
Error	1.52		

$F_{.01;\ 1,29} = 7.60$

$F_{.05;\ 1,29} = 4.18$

APPENDIX D

CORRELATION COEFFICIENTS FOR LEVEL OF SIGNIFICANCE BETWEEN GROUPS

Comparison of Level of Significance between paired dependent variables for groups 1 and 2

Source		Z Score
50m. Final time - Anaerobic power		1.80
50m. Final time - Sprint distances	- 5	1.36
	- 10	.12
	- 15	.35
	- 20	1.05
	- 30	.92
	- 40	.22
	- 50	-
50m. Final time - Hamstring Machine		.53
- Running Machine		1.59
- Leg Dynamometer		.36
Anaerobic power - Sprint distances	- 5	1.52
	- 10	1.13
	- 15	1.85
	- 20	.64
	- 30	1.59
	- 40	.08
	- 50	1.22
Anaerobic power - Hamstring Machine		1.87
- Running Machine		.61
- Leg Dynamometer		.57

$Z_{.01;\ 12,11} = 2.58$

Comparison of Level of Significance between paired dependent variables for groups 1 and 3

Source		Z Score
50m. Final time - Anaerobic power		-
50m. Final time - Sprint distances	- 5	1.28
	- 10	1.21
	- 15	1.17
	- 20	1.72
	- 30	-
	- 40	.44
	- 50	.34
50m. Final time - Hamstring Machine		.81
- Running Machine		1.01
- Leg Dynamometer		.66
Anaerobic Power - Sprint Distances	- 5	.05
	- 10	.65
	- 15	.15
	- 20	.08
	- 30	.01
	- 40	1.07
	- 50	.26
Anaerobic power - Hamstring Machine		.65
- Running Machine		.35
- Leg Dynamometer		.66

Z.01; 12,12 = 2.58

Comparison of Level of Significance between paired dependent variables for groups 2 and 3

Source	Z Score
50m. Final time - Anaerobic power	1.96
50m. Final time - Sprint Distances - 5	1.19
- 10	1.29
- 15	1.56
- 20	.62
- 30	1.04
- 40	.11
- 50	.24
50m. Final time - Hamstring Machine	1.31
- Running Machine	.60
- Leg Dynamomoter	.31
Anaerobic power - Sprint distances - 5	1.47
- 10	1.76
- 15	1.70
- 20	.64
- 30	1.62
- 40	.95
- 50	1.47
Anaerobic power - Hamstring Machine	1.24
- Running Machine	.89
- Leg Dynamomoter	

Z.01; 11,12 = 2.58

Comparison of Level of Significance between paired dependent variables for groups 1 and 4

Source		Z Score
50m. Final time - Anaerobic power		1.10
50m. Final time - Sprint Distances -	5	.34
	- 10	.19
	- 15	.22
	- 20	1.92
	- 30	.78
	- 40	1.50
	- 50	.27
50m. Final time - Hamstring Machine		.67
- Running Machine		.55
- Leg Dynamomoter		.37
Anaerobic Power - Sprint distances -	5	1.69
	- 10	.69
	- 15	.02
	- 20	.54
	- 30	1.69
	- 40	.21
	- 50	.40
Anaerobic power - Hamstring Machine		.36
- Running Machine		.12
- Leg Dynamomoter		.35

Z.01; 12,6 = 2.58

Comparison of Level of Significance between paired dependent variables for groups 2 and 4

Source	Z Score
50m. Final time - Anaerobic power	.21
50m. Final time - Sprint distances - 5	.65
- 10	.28
- 15	.50
- 20	1.15
- 30	.10
- 40	1.68
- 50	.27
50m. Final time - Hamstring Machine	.96
- Running Machine	.59
- Leg Dynamomoter	.63
Anaerobic power - Sprint distances - 5	.55
- 10	.14
- 15	1.35
- 20	.96
- 30	.53
- 40	.30
- 50	.53
Anaerobic power - Hamstring Machine	1.00
- Running Machine	.51
- Leg Dynamomoter	.07

Z.01; 11,6 = 2.58

Comparison of Level of Significance between paired dependent variables for groups 3 and 4

Source		Z Score
50m. Final time - Anaerobic power		1.21
50m. Final time - Sprint distances	- 5	.57
	- 10	.67
	- 15	.63
	- 20	.70
	- 30	.86
	- 40	.35
	- 50	.15
50m. Final time - Hamstring Machine		.17
- Running Machine		.17
- Leg Dynamomoter		.84
Anaerobic power - Sprint distances	- 5	1.63
	- 10	1.15
	- 15	.12
	- 20	.47
	- 30	1.71
	- 40	.98
	- 50	.52
Anaerobic power - Hamstring Machine		.11
- Running Machine		.14
- Leg Dynamomoter		.12

Z.01; 12,6 = 2.58