AN ABSTRACT OF THE THESIS OF

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Donald E. Campbell

The purpose of this investigation was to determine the sprint start time to the first 10 and to the second 10 meters as a result of alteration of starting block angles and lateral block spacings.

One male world class, two female college level, one male and one female high school level sprinters served as subjects. During the test period each subject completed twelve 20-meter sprints. Sprint starts were made from combinations of 52.5, 65, and 75 degrees front starting block angle and 60 and 80 degrees rear starting block angle from a 4 inches and a 10 inches lateral block spacing.

A subjects by treatments analysis of variance indicated a significant difference in time over the first 10 meters as a result of the alteration of block angle and lateral block spacing but no significant difference was obtained for the second 10-meter. Combination of 65 degrees front angle with 60 degrees rear block angle, and 75 degrees front angle with 60 degrees rear block angle were significantly different

based on Duncan's new multiple range test. Significant difference in time by the subjects was found for all combinations of block angles for both the first 10 meters distance and for the second 10 meters distance. Based on Duncan's new multiple range test, male subjects performed significantly different than female subjects. A multiple linear regression procedure and a rank order correlation established that a significant difference existed in the independent variables that would predict the start time for the identified block combinations. FF2P, the second peak of resultant force of front foot, FVF2P, the second peak of vertical resultant force of front foot, and FRH, horizontal resultant force, were the independent variables most commonly identified although the contribution order was not the same. Little concordance existed in the rank of independent variables among the three significantly different combinations.

Resultant force and resultant force angle, combinations of block angles and lateral block spacing, and sprint start time formed a mutual dependent relationship in this study.

If an optimal model of statistical relationship between resultant force and resultant force angle, and combinations of block angles and lateral block spacing could be set up, the range of block angle and lateral block spacing variations could be minimized.

Combinations of Block Angles and Lateral Block Spacings on Sprint Start Time

by

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CHAPTER I

INTRODUCTION

In competition, the first and last place sprinters often differ by only a few hundredths of a second in time. Consequently most sprinters recognize that a good start can be a decisive factor in a race. Physical educators and coaches are in general agreement that an efficient start is essential for maximal performance in sprint races.

Stampfl(1956) suggested that the sprint start is an integral part of the total race and consequently is not distinct from the entire sprinting event. He stated that the important thing is to reach top speed as quickly and smoothly as possible, and this can only be done if the rhythm of the stride begins actually in the starting blocks. Obviously, movement from the start position in the sprint start must not only be fast and forceful but should also permit the sprinter to rapidly take a mechanically efficient running position.

Bunn(1955), in his description of an effective start, stated that in starting, the emphasis is upon getting away from the mark as quickly as possible so that the desired pace can be developed in the shortest distance. He also stated that the ideal starting position is one that permits the greatest amount of force to be exerted over the longest distance in the desired direction, as a means of overcoming inertia. Therefore, researchers should realize that the sprint start effects more than one aspect of performance before concluding which technique is superior. If an investigation only focuses on specific aspects of performance, for example, the magnitude of the force exerted against the starting blocks or the running velocity, the applicability of the results will necessarily be limited. Historically, sprinters have looked at the start only as a way to achieve a lead early in the race.

Most of the investigations measured either the magnitude of the force exerted against the starting blocks or the effect of the anterior-posterior foot spacing on the start. Because these methods were used, the conclusions of the past investigations were often in disagreement with one another. This has led to confusion among track coaches and researchers.

Mechanically there are many factors which might influence performance, such as the force exerted on the starting blocks, including the normal and tangential components, the speed of departure from the blocks, the block angle and the acceleration after leaving the blocks. An extensive review of literature concerned with the mechanics of the sprint start indicated that no investigator has examined all of these factors at the same time. Thus, the proper combination of these factors that would be most advantageous to a successful start needs to be investigated.

Due to advances in technology and more qualified investigators, considerable improvement has been made both in research technique and in research equipment in the last one hundred years. Althouqh photography plays a very important role in sport science, ultrasonic measuring technique presented by Hennig and Nicol(1976), has made direct measurement of velocity possible.

In the past, starting blocks were adjustable, not only in terms of lateral spacing but also block angle. It is generally believed, however, that 45 degrees and a little less than 90 degrees is the best combination for the front and rear blocks respectively. Sprinters have used a combination which is most comfortable and efficient in getting out of blocks. It is not certain, however, whether an optimum combination of front and rear block angles exists. This question has served as the stimulus for the present study.

Purpose of the Study

The purpose of this investigation was to determine the sprint start time to the first and the second 10 meters as a result of alterations of starting block angles and lateral block spacings.

Hypotheses

The following null hypotheses were tested.

Hypothesis 1: No significant difference would exist in time from start to the first 10 meters and to the second 10 meters among combinations of block angles and lateral block spacing.

Hypothesis 2: No significant difference would exist in time from start to the first 10 meters and to the second 10 meters among subjects performing combinations of block angles and lateral block spacings.

Hypothesis 3: No significant difference in the rank order of the independent predictor variables determined by forward selective stepwise multiple regression that would predict dependent variable time.

Limitations

This study was restricted to:

a. Use of ultrasonic and electro-timing techniques to determine time and velocity.

b. Use of a set of strain gauge starting blocks to determine forces.

c. Medium crouch with subject's preferred anterior-posterior spacing.

d. Use of five subjects from three different levels of performance.

e. Use of a distance of 20 meters from the starting line.

Delimitations

Results of this study on three female and two male subjects may provide limited interpretation for general practice.

Definitions of Terms

Anterior-Posterior Block Spacing referred to the distance from toe to toe.

Lateral Block Spacing was the distance between blocks laterally.

Preferred Kneeling Start was the position that the sprinter used in training and in competition.

Block Angle was the acute angle formed by the surface of the starting block and the horizontal.

Take-Off Angle was the angle between the horizontal and an imaginary line of the direction of total resultant force when the subject was at the last instant of contact with the front foot.

Take-Off Accleration was the rate of change in velocity recorded at specified time intervals during the time the subject was at the last instant of contact with the block. Block Time was the total period of time from the gun shot until the subject was no longer in contact with starting blocks.

Duration of Forces on the front block and the rear block was the time elapsed from the first appearance of a force on the front block and the rear block, respectively, after the starting signal until the feet were removed from their respective blocks.

Reaction Time was the time elapsed between the starting signal and the first occurrence of a force on the force recording.

Reaction Impulse about the subject's center of gravity was the vector quantity obtained by measuring the resultant moment of horizontal and vertical forces about the center of gravity of the athlete and multiplying it by the specified interval of time of force application.

CHAPTER II

REVIEW OF LITERATURE

In this section the most important investigations related to the kinematics and kinetics of the kneeling start are reviewed. The performance of the start is affected by certain aspects of the kneeling start position. The topics presented in this section including the following (1) block spacing (a) anterior-posterior, (b) lateral, (2) force development, (3) reaction time and level of ability of subject, (4) sprint running, (5) ultrasonic device, and (6) summary.

Block Spacing

Numerous investigations on block spacing have been done since 1900. Most of the investigations concentrated on anterior- posterior spacing, while only a few discussed the problem of lateral spacing.

Anterior-Posterior Block Spacing

Three main types of kneeling start are the bunch or the medium and the elongated. The main difference among these types of starts lies in the anterior-posterior spacing. Anterior-posterior spacing is the distance from the toes of one foot to the toes of the other. For a long period, the bunch start was generally accepted as the best technique. Dickinson(1934) observed 26 trained sprinters using four different foot-spacings. On the basis of 832 starts for a distance 2.5 yards, he found that the bunch start yielded a significantly faster starting time than the medium start, which in turn was faster than the enlongated start. In 1934, Kistler studied the thrust of the starter against the blocks in the different sprint starting positions. He found that the pressure exerted by both feet against the starting blocks varied in the following descending order: 26 inch spread, 21 inch spread, 16 inch spread and 11 inch spread. This implied that in general the larger the foot spread in the starting position, the greater the foot-pounds of pressure exerted against both starting blocks. Results reported by Henry(1952) indicated that the 11 inch (distance from toe to toe) bunch start allowed the fastest clearence of the blocks but with less velocity. Thus, the 11 inch spread resulted in a slower time at 10 and 50 yards, when compared to 16, 21 and 26 inch spreads. From his results it was clear that the 16 inch to 21 inch toe to toe distance was optimal. Henry also noticed that the bunch start appeared to enable the sprinter to leave the blocks in less time but resulted in a slower velocity and produced slower times at distance of 10 yards. An elongated foot spacing permitted a greater velocity when leaving the blocks, however, this advantage seemed to be lost within the first 10 yards. The best runs at 10 yards and 50 yards resulted from the 16 inch foot spacing.

Kistler(1934) and Henry(1952) reported similar conclusions, which contradict the findings of Dickinson (1934). Kistler and Henry stated that force of the foot spacing and the force of the rear leg were greater when the foot spacing was increased. Contradictions in their finding may be resolved by considering the possible disadvantage of time lost in securing a forceful thrust. White(1940) concluded that when using a bunch start, high hip elevation was significantly superior to a low hip position in the first step of the race. Stock (1962) reported that by using a medium block spacing and elevating the hips which increased the angle of the rear knee joint to 165 degree flexion sprint time at 50 yards.

Lateral Block Spacing

Few investigations have been done on optimal lateral spacing between starting blocks. Hultstrand (1965) conducted the only study found dealing with lateral foot spacing in the sprint start. This study was concerned with variations of lateral block placement relative to pelvic width in women. The subjects were classified as narrow-, medium-, and wide-hipped according to the widths of their greater trochanters. The lateral block spacing corresponded to the mean hip widths of the three groups. She found that the variations of lateral foot placement did not significantly affect the sprint start for women.

Rohrer (1971) investigated the stagger start and the square start with the feet equal distance from the starting line. He concluded that an initial, simultaneous thrust with both feet equal distance from the starting line and approximately hip width apart appeared advantageous for the inexperienced subjects who had the fastest mean times at 10 yards and 20 yards in the square position with a 10-inch lateral spacing. The mean difference among the eight positions was not significantly different. The experienced sprinters were significantly faster at 10 yards and appreciably faster at 20 yards when starting from their normal starting position, a medium staggered start with a 3-inch lateral spacing. The square position with a 5-inch lateral spacing was second best for initial acceleration. Wider lateral spacings were detrimental.

Force Development

Kistler (1934) studied force development of 30 trained sprinters, using spring scales attached to the starting blocks. He reported that the greater impulse was provided by the front leg. Henry (1952) used a chronograph to measure the horizontal component of force as a function of time. He found that the duration of the force applied on the rear block did not change tremendously. The duration of force application increased with an increase in anterior-posterior block spacing. He also stated that because of the longer duration of force application, the front leg contributed much more to the development of velocity, even if the rear leg developed a maximum force much larger than that by the front leg.

Bandejkina(1962) used 66 males and 27 females of different levels of ability in sprinting to investigate the duration of the pushing force on the blocks. She found that force was either initiated by both feet or by the rear foot in good sprinters. The faster sprinters usually had a longer delay between the initiation of the force on the rear block and the front block. She also stated that the total maximal force applied horizontally on the two blocks was usually 30 kilograms greater than the subject's body weight. In her study of force-time curves, she found that good sprinters usually produced two peaks in the front force curves, with a minimum reduction of force occurring between them.

Payne and Blader (1970) investigated the forces applied to the front block and the rear block by measuring the forces which were normal and tangential to the blocks and calculating the torques developed around a horizontal- lateral axis. The findings revealed that in an elongated start position the sprinter clears the blocks later but gains more velocity, while in the bunch start the sprinter has shorter block time, but leaves with a lower velocity.

Reaction Time and Level of Ability of Subject

Various investigators (Toomsalu 1963, Rowell 1967 etc.) have recorded reaction time in sprinters and have found that the range was approximately 0.115 to 0.118 seconds. Henry(1952) concluded that reaction time was uncorrelated with speed in the sprints and was not influenced by block spacing.

Ogawas(1964) found that the more skilled athletes have faster reaction times while the less skilled subjects exhibited irregular and shorter strides over the first strides. Barlow and Cooper(1972) reported similar conclusion. They found that in all sprint trials the runner who had the best record of performance always had the shortest reaction time.

Henry(1952) concluded that the best sprinters were characterized by a regular impulse. This means they were capable of applying maximum force on the front block very quickly and maintaining it during the period of contact with the blocks. Less skilled sprinters started to apply force on the front block very gradually and reached the peak force just before leaving the blocks. They applied relatively smaller forces on both of the blocks than the skilled sprinters.

Sprint Running

The time or distance required by the sprinter to reach high speed has been investigated by numerous researchers. The results of factor analytic research indicated that sprint running is a basic ability of human motor performance. Maximal running speed is attained at the moment when a balance is established between the muscle efforts expended by the runner and the forces of internal and external resistance. Bunn(1962) stated that full speed is gained after about 10 yards. Hill(1927) found that the highest speed was attained between 30 and 50 yards, while Henry(1952) reported a longer distance, which was reached about 6 seconds after the start. Henry and Trafton (1951) used 25 inexperienced runners and found that 90% of the maximum velocity was reached in 15 yards, and 95% in 22 yards.

Ikai(1968) used a photo-sensitive cadmium cell connected to an oscillograph at 14 different distances to study the velocity curve. He found that skilled sprinters had two peaks of high velocity, one at 35 to 45 meters and a higher one at approximately 75 meters. A slight decrease in velocity occurred during the last meters of the race. He also found that the pattern of running development appeared unaffected by age beyond the age of 16 in boys and the age of 11 in girls. Only the intervention of appropriate training methods would improve running thereafter. Margaria(1966), stated that maximal efforts can be maintained by the runner for a period of 5-6 seconds. Volkov and Lapin(1979) stated that the maximal speed in sprint running is attained 4-5 seconds after the start. Over that period, the oxidative aerobic processes in tissues do not have enough time to unfold to any substantial degree. Henry and Trafton(1951) also stated that the sprint-velocity curve was of a two-component form. One component was primarily velocity and the second component primarily acceleration.

Dyson(1959) describes the first stride in the sprint start as a phase of greater positive acceleration which is the result of large horizontal and small vertical components of force. However, in contrast to Dyson's description, Barlow and Cooper(1972) found that in each sprint trial all three performers consistently developed greater vertical force than horizontal forces. They also reported that a braking force occurred as subjects struck the platform which was only for a small fraction of a second but was important because it actually represented a short period of deceleration. They suggested that it is desirable not only at the start but also throughout the race that a sprinter attempt to keep his braking force to a minimum. This could be accomplished by keeping the center-of-mass as directly over the base of support at touchdown as possible and by having the supporting leg moving to the rear at a velocity at least equal to that of the forward velocity of the runner.

Ultrasonic Velocity Measurement

As early as 1887, Marey demonstrated a method for the measurement of time-dependent displacement of the human body while walking, which applied small intermittent lighting lamps to the body of the moving subject while the shutter of a camera was opened (Cooper and Glassow). This technique is still practiced today by the use of modern light-emitting-diodes, and stroboscopic devices. In 1887, Muybridge used 24 cameras, with synchronized shutter devices, to show photographic series of a moving subject. In 1974, a new device (SELSPOT), based on lateral photo effect of silicium diodes, was introduced by Woltring. Use of the SELSPOT involved on-line information via electronic processing, but the costs were so high that few laboratories could afford it. A year later, ultrasonic velocity measurement was presented by Hennig and Nicol(1976) and direct measurement of velocity became possible. Using the phenomenon of the acoustical Doppler-effect, when an acoustical transmitter is moved relative to a stationary receiver, a frequency is recorded on the receiver that is dependent on the speed of the transmitter. Movement of the sound source in the direction of the receiver results in a shift in frequency that leads to an increase in the reception frequency. A decrease is registered for movement away from the receiver. When the subject is limited to transmitter speeds that are low compared to the speed of signal propagation, the shift in frequency is approximatly proportional to the transmitter speed. The formula used by Hennig and Nicol to calculate ultrasonic velocity measurement is given below:

$$\Delta f = f \times v / c \times \cos 0$$

$$v = f \times c / f \times \cos 0$$

where f_o = transmitter frequency

Δf = shift in frequency

v = speed of transmitter

c = speed of sound

θ = angle between the direction of movement and the line from the transmitter to the receiver.

By shifting the frequency between the transmitter and receiver it is possible to determine the speed of the transmitter. Thus the velocities of a number of body surface points during a movement process can be measured both continuously and simultaneously from a measuring station, provided there are sound sources of different frequencies on the body surface points.

Summary of Review of Literature

Most investigations on kneeling starts studied anterior- posterior block spacing. The bunch start appeared to enable the sprinter to leave the blocks in less time, but resulted in a slower velocity at a distance over 10 yards. An enlongated foot spacing permitted a great velocity when leaving the blocks, but this advantage seemed to be lost within the first 10 yards. Many investigations found that the best block spacing is a medium foot spacing (Kistler 1934, Henry 1952, Stock 1962.)

The review of literature indicated that only one investigation had been done on lateral block spacing and no study had been done on block angles in the sprint start.

Many investigations found that the greater impulse was provided by the front leg.(Kistler 1934, Henry 1952, Bandejkina 1962, Payne and Blader 1970.) Good sprinters usually produced two peaks in the force curves with a minimum reduction of force occurring between them.(Bandejkina 1962)

Reaction times was uncorrelated with speed in the sprints and was not influenced by block spacing.(Henry 1952) A normal running pattern was achieved in about 10 yards while maximum speed was attained between 30 to 50 yards, in other words in 4 to 5 seconds.(Hill 1972, Henry 1952, Bunn 1962, Ikai 1968)

With respect to research methods, most investigators used cinematography which is currently the most used technique for biomechanical analysis of movement. Compared to ultrasonic velocity measurement, photography and cinematogrophy have some disadvantages. For example, immediate feedback is not possible, the evaluation process requires time, and it is very difficult to interpret the acceleration records. These problems can be solved by using ultrasonic velocity measurement, which can directly measure the velocity for the determination of mechanical quantities.

CHAPTER III

METHODS AND MATERIALS

The purpose of this investigation was to determine the sprint start time to the first and the to second 10 meters as a result of alterations of starting block angles and lateral block spacings. This chapter includes the following sections: pilot study, subjects, instrumentation, test procedures, anthropometric measurements, methods of computation and techniques of data analysis.

Pilot Study

A pilot study was conducted during the Spring Term of 1980 at The Pennsylvania State University. The purpose of the pilot study was to determine the optimum procedures and measurable parameters. One subject was used who performed several trials under twelve different sprint start conditions. Through the pilot study the following factors were determined - proper placement of setting for ultrasonic velocity measurement, proper paper speed, channels of ultra violet recorder, block angle, number of trials, sequence of trials, and track site.

Subjects

Five subjects from three different levels were chosen for this study. Subjects consist of one male of world ability level, two females of college age, and one male and one female of high school age. Subjects ranged from one to ten years in competitive sprinting experience. The subjects were selected on the basis of competitive records and recommendation of their coaches and willingness to participate in the investigation.

Instrumentation

Starting Blocks

A set of starting blocks as shown in Figure 1, was made in the Applied Research Laboratory at the Pennslyvania State University. The set of starting blocks was used for this study because it easily adjusted to the various starting positions. The following adjustments could be made on the starting blocks to accomodate each experimental combination. Anterior-posterior spacing could be adjusted up to 36 inches. Lateral spacing could be varied from 4 inches to 20 inches wide. Block angle could be adjusted easily from 52.5 to 90 degrees at 2.5 degree intervals. Six starting block angle positions and two different lateral block spacings formed twelve treatment combinations as illustrated in Figure 2.

In order to accomplish the data analysis, several cells were combined to larger units. Cell combintions are presented in Table 1. The set of starting blocks had strain gauge elements sensing both normal and tangential forces applied to the blocks (see Figure 1). An important characteristic of this set of blocks was that the application of a given force to any part of the starting block produced the same results.

Calibration

Laboratory tests were made to verify the independence of forces applied along the two directions and the linearity of these forces. Calibration of each normal and tangential force was done by loading known weights upon the blocks in the horizontal and then the vertical direction. Weights were loaded upon the surface of the blocks from 50 pounds up to 200 pounds in 50 pounds increments. The vertical loading was performed by hanging known weights vertically on the cable. Weights were hung vertically under the edge of the block from 0 pound to 100 pounds in 50 pounds increments. One force at a time was produced and these signals were recorded from the electrical assembly of the gauges connected to a analog voltmeter. This method was repeated several times and the results provided a linear relation for the range of forces used in this study.

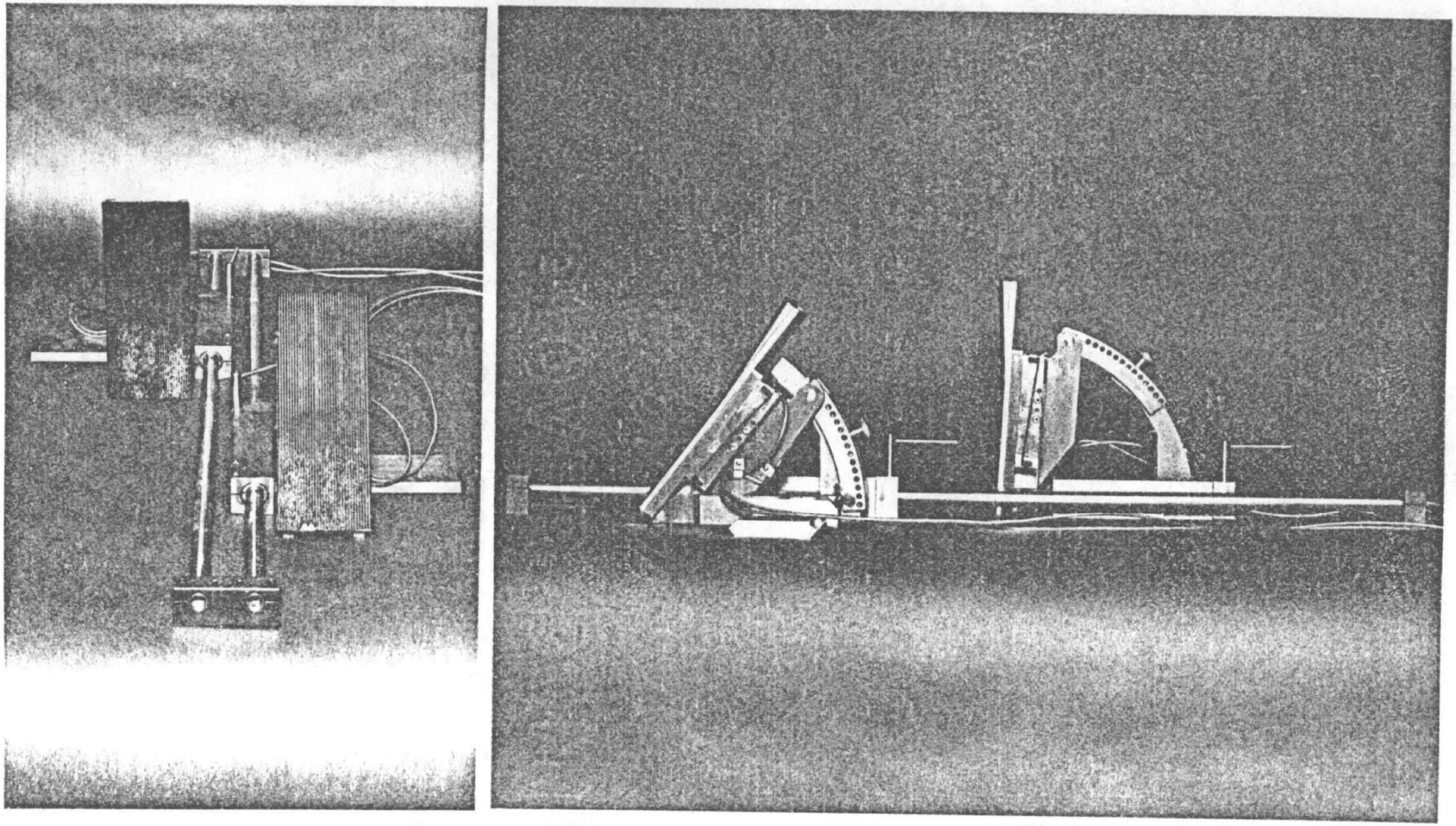

Figure I. Instrumented starting blocks

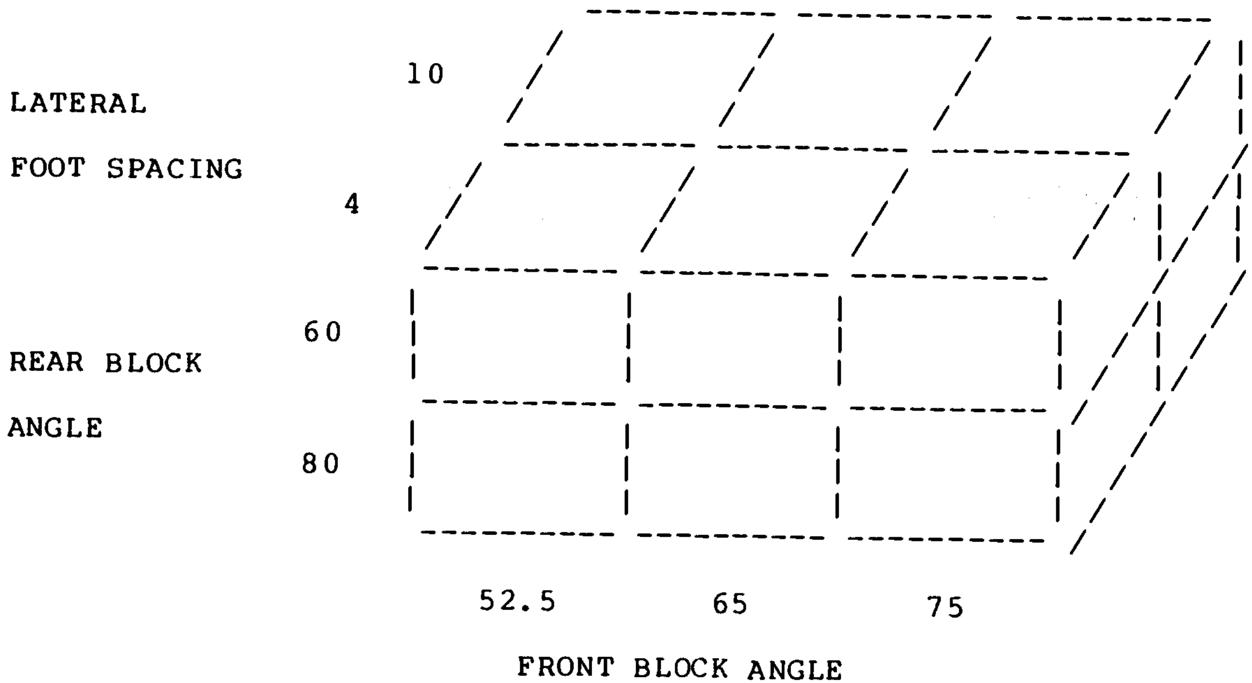

Figure II. Twelve combinations of block angles and block spacings.

Table 1. List of combinations of block angles and lateral block spacings

Combination			Description					
LS	FBA	RBA	Lateral Spacing (inch)	Front Block Angle (degree)			Rear Block Angle	
ALL	ALL	ALL	10 & 4	52.5	65	75	60	80
4	ALL	ALL	4	52.5	65	75	60	80
10	ALL	ALL	10	52.5	65	75	60	80
ALL	ALL	60	10 & 4	52.5	65	75	60	
ALL	ALL	80	10 & 4	52.5	65	75		80
ALL	52.5	ALL	10 & 4	52.5			60	80
ALL	65	ALL	10 & 4		65		60	80
ALL	75	ALL	10 & 4			75	60	80

Ultrasonic Velocity Measurement

Hennig and Nicol(1976) used the accoustical Doppler effect in devising a method for the direct determination of velocity for use of biomechanics. When an accoustical transmitter is moved relative to a stationary receiver, a frequency is recorded on the receiver. The frequency is dependent upon the speed of the transmitter (see Figure 3). By using a frequency-voltage conversion, the velocity of the transmitter was recorded as an analog signal.

The transmitter was put on a belt fastened on the subject's waist so that the transmitter was at the small of the back and facing a stationary receiver. A receiver was adjusted to the height of the transmitter.

Electronic Timing System

An electronic timing system as shown in Figure 3 was used. This system, which was composed of two phocells, was located at 10 and 20 meters from the starting line. The electrical circuit was interrupted when the gun shot occurred and when the subject passed by the two photocells. The timing system provided elapsed time from the firing of the gun to 10 meters and to 20 meters.

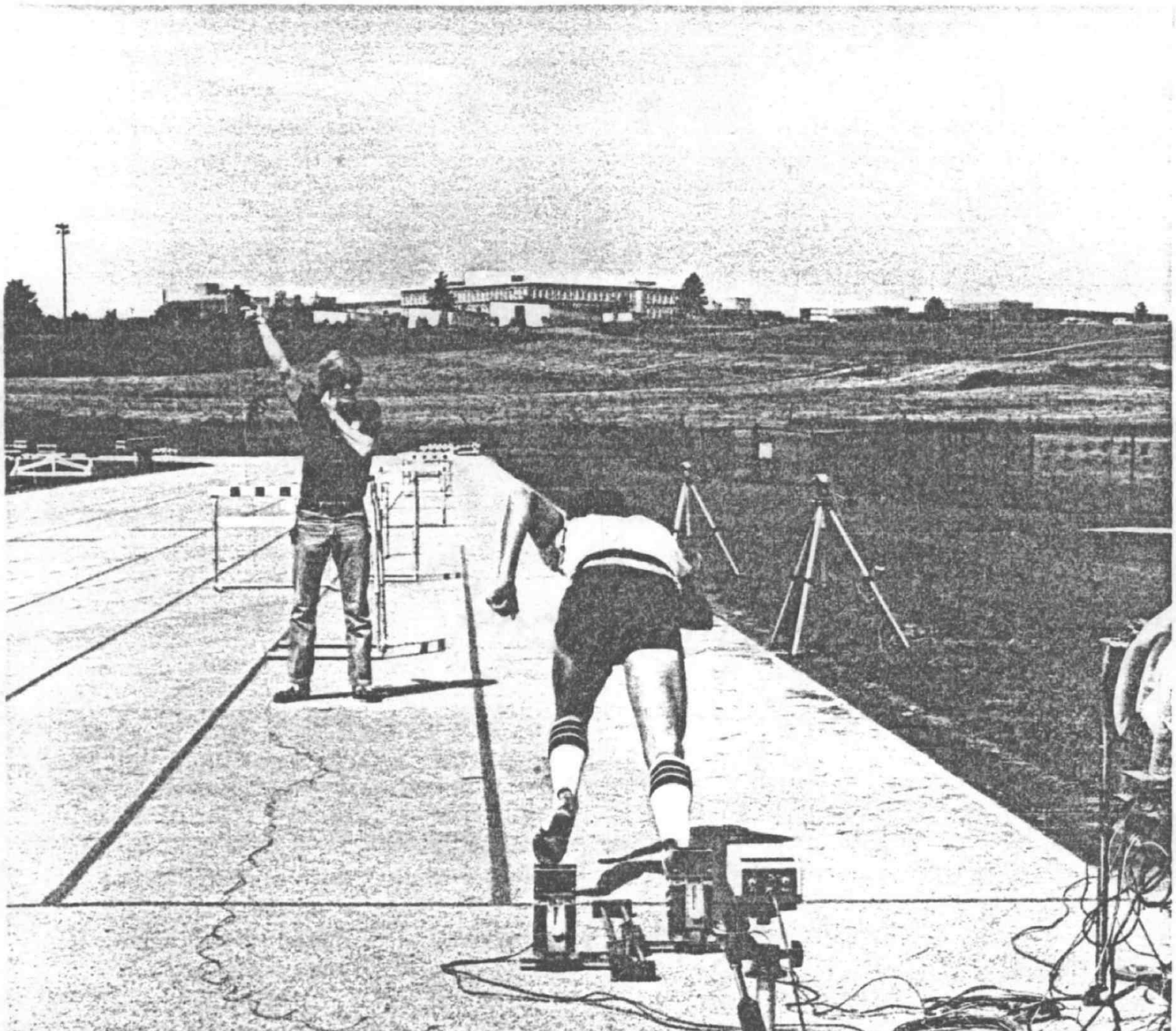

Figure III. Ultrasonic velocity measurement

Electronic timing system

Ultra Violet Recorder

A six channel ultra violet recorder as shown in Figure 4 was used to record normal and tangential forces and to plot the velocity curve of the subject moving from the firing of the gun to the 20-meter mark. Results were recorded on light sensitive paper. The paper speed was set at 10 centimeter per second. Six channels of data were obtained for each trial.

The total number of channels of data required in this study was established at six. One channel recorded time from the start to 20 meters. Four channels recorded force to include front foot normal force, front foot tangential force, rear foot normal force, and rear foot tangential force. One channel recorded velocity.

Anthropometric Measurements

The anthropometric measurement included body height and weight, total leg length and hip width. The leg length was measured from the base of the heel to the greater trochanter. Hip width was measured from tubercle of the crest of the illium to the other. Anthropometric measurements are presented in Table 2.

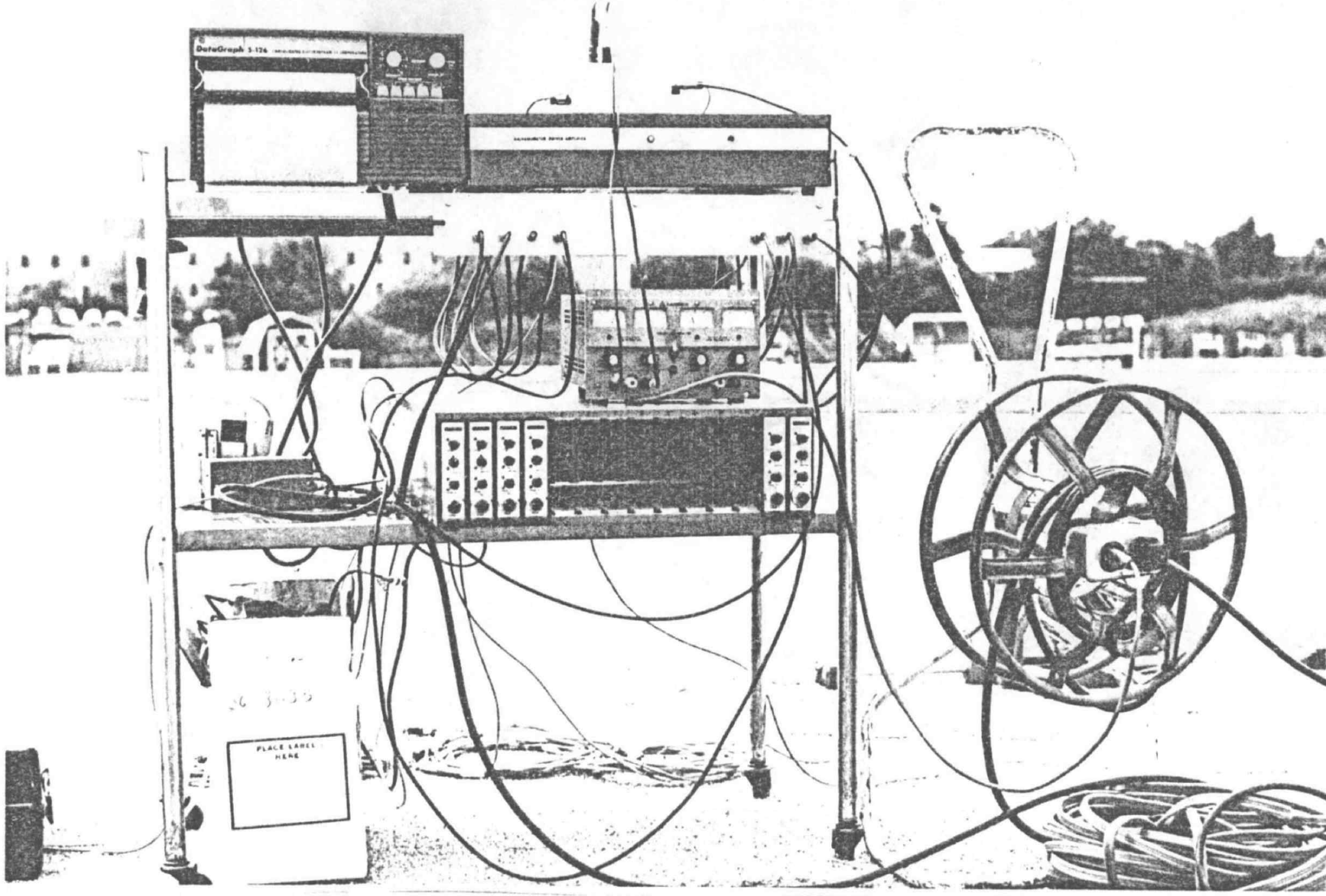

Figure IV. Six channel ultra violet recorder

Table 2. Anthropometric measurements of subjects

Characteristics	Subjects 1	2	3	4	5
Age (years)	18	25	16	20	15
Height (cm)	175.2	185.4	180.3	165.1	166.9
Weight (kg)	68.2	90.0	71.4	61.8	48.6
Leg Length (cm)	105.0	112.5	104.5	96.0	97.0
Hip Width (cm)	32.7	34.5	31.8	32.0	29.0
Anterior-Posterior Distance between Blocks (cm)	23.0	19.0	25.0	24.0	18.0
Distance from Starting Line to Front Block (cm)	11.0	17.5	19.0	11.0	10.8
Sex	Female	Male	Male	Female	Female
Level	College	World	High	College	High
Sprint Performance over 100 m (sec)	12.6	10.1	11.1	12.3	13.1
Best Time during 79-80	12.6	10.5	11.1	-	13.1
Experience (year)	5	10	5	7	1

Test Procedure

The general instructions for the timing and recording sessions were given to all the subjects during the two test days. The order in which each subject performed combination of block angle and spacing was randomly assigned.

During a testing period, trials of each combination were conducted in the order that had been randomly assigned. The same randomly chosen order was followed for each of two test days.

During the two day test period a subject ran twelve 20-meter sprints. Each day sprints were made from the 52.5, 65 and 75 degree front starting block angles combined with the 60 and 80 degree rear starting block angles. A 4 inch lateral block spacing was used on the first test day and a 10 inch was used spacing on the second day.

The testing sequence for a trial was as follow:

1. The investigator consulted the individual subject's data card and took anthropometric measurements of hip width, leg length, body weight and height.
2. The blocks were adjusted to proper spacing.
3. The subject was fitted with belt which had transmitter fastened onto it.
4. The Ultra Violet recorder and electrical leads to the startina blocks and ultrasonic velocity measurement

device were properly connected.

5. When the starter gave the command, "on your mark" to the subject, the tester reset the Ultra Violet recorder to stand by.
6. The subject resumed the "on your mark" position.
7. The investigator assertained that the toes of the subjects were in contact with the ground and that the surfaces of the shoes were in contact with the starting blocks.
8. When the command "set" was given, the investigator activated the Ultra Violet recorder and the subject moved to set position.
9. Following an interval of approximately two seconds, during which the subject was motionless, the pistol was discharged. If the start was improper as indicated on recording paper, the trial was repeated. Following a rest of approximately three minutes the subject resumed the test sequence.
10. Following the sound of the pistol, the subject pushed out of the starting position and sprinted the 20-meter distance.
11. The investigator determined that the subject had passed through the mark, then turned off the Ultra Violet recorder.
12. The investigator checked the direct output data to determine if the trial was good, and the subject was in-

formed of the 10-meter and 20-meter times, reaction time and the magnitude of the forces applied against the two blocks. The subject was also complimented on the effort and encouraged to do even better on the next trial.

13. The investigator set the starting blocks in a new experimental combination while the subject returned to the starting blocks for the next trial.

Data Reduction

The analysis of the recording data was done in the Biomechanics Laboratory and Computation Center of The Pennsylvania State University and the Computer Center of Oregon State University .

Forces

The strain gauge elements of the starting blocks detected the normal force and tangential force applied on each block independently. Peak normal and tangential forces were measured from the force-time curves. A ruler graduated in millimeters was used to measure the peak force curves from the base line. All measures were duplicated until consistent results were achieved. The horizontal and vertical components of normal (Fn) and tangential (Ft) forces were calculated trigonometrically and sumed algebraically to produce the actual vertical (Fv) and horizontal (Fh) forces. Horizontal and vertical forces were added vectorially to obtain the actual resultant force. After determining the resultant peak force, the sprinters' take-off angles were calculated. The following formula were applied:

$$N1V = N1Sin\theta$$

$$N1H = N1Cos\theta$$

$$T1V = T1Sin\theta$$

$$T1H = T1Cos\theta$$

$$\text{Total } V = T1V + N1V$$

$$\text{Total } H = T1H + N1H$$

$$\text{Resultant Force} = \sqrt{(N)^2 + (V)^2}$$

$$\text{Actual Resultant Force Angle}$$

$$= Tan^{-1}(V/H)$$

Computer programs were used to calculate forces, times, angles, velocity and acceleration. The statistical package for the Social Sciences (SPSS) and statistic interaction programing system (SIPS) were used to analyze data at Oregon State University Computer Center.

Time

Time was recorded in two ways. One was a timing generator which produced a mark each tenth of a second on recording paper of ultra violet recorder while the paper was running. Another was the time from the gun shot mark until the subject ran through the two photocells in a trial. In order to minimize the error which might be produced by noise of the equipment, displacement of 1/10 second timing mark was measured many times, and mean time interval was determined to be 11 centimeters per second.

Velocity Curves

Velocity was recorded with an ultrasonic measuring device from the time of the gun shot until the subject ran through the second photocell located at the 20 meter mark. The calibration factor was :

1.75 cm. on recording equivalent to
a velocity of 2.0 m./sec.

The range of error was .02/1.75*2 m./sec. from the velocity data. Average acceleration was calculated using the formula:

$$a = dv/dt = (Vf - Vi)/dt$$

Data Analysis

Criterion Measures

Criterion measures used in this study were presented in Table 3.

Twenty-two variables were derived for independent and dependent variables after raw data were processed. The first analysis of data showed high correlations between independent variables and dependent variables. Average acceleration and average velocity were highly correlated with dependent variables running time up to 20 meters. This is more or less self evident. Therefore the first data reduction was made. Eight independent variables and 3 dependent variables were chosen for this study. Analysis of data after the first data reduction showed that the multiple correlation was much lower after this data reduction.

Because of a non-linear relationship among resultant force angles, the higher order terms, quardratic and cubic, were applied to predict the dependent variable, thereby expanding linear multiple regression to curve- linear multiple regression.

Analysis of data showed that adding additional quardratic terms of resultant force angles produced a better fit to the model, while the improvement due to cubic terms was not significant. Based on these reasons the second data reduction was made. 14 variables including quardratic terms were chosen to test the hypotheses.

Table 3. List of independent and dependent variables

	Description
Dependent variables	
T10M	running time during the first 10 meters.
T10-20M	running time during the second 10 meters.
T20M	running time during the first 20 meters.
Independent variables	
FF1P	front foot resultant force of the first peak in per cent of body weight.
FF2P	front foot resultant force of the second peak in per cent of body weight.
FVF2P	front foot vertical force of the second peak in per cent of body weight.
AF1P	front foot of resultant force angle of the first peak.
AF2P	front foot of resultant force angle of the second peak.
FRV	rear foot vertical force in per cent body weight.
FRH	rear foot horizontal force in per cent body weight.
AR	rear foot resultant force angle.
AF1P2	quadratic term of AF1P.
AF2P2	quadratic term of AF2P.
AR2	quadratic term of AR2.

Data analysis

Four different statistical methods were applied in order to test the hypotheses of this investigation. Analysis of Variance (ANOVA), subjects by treatments served to test the null hypotheses 1 and 2. Small values of the calculated F-ratio would support the hypotheses, which would mean no significant difference between subjects or trials, whereas large values would lead to a rejection of the hypotheses. For those cases with a significant difference between subjects or trials, Duncan's New Multiple Range Test was applied additionally in order to make a statement about which combinations were significantly different.

The first step to test Hypothesis 3 was to use forward selective stepwise multiple regression which would yield a order among the independent variables which would predict time to the first and the second 10 meters. These rankings served as basis to a rank order correlation analysis to finally accept or reject Hypothesis 3.

All hypotheses were tested at .05 level of significance.

CHAPTER IV

ANALYSIS AND INTERPRETATION OF DATA

The purpose of this investigation was to determine the sprint start time to the first 10 meters and to the second 10 meters as a result of alteration of starting block angles and lateral block spacing.

The results and statistical analysis performed for this study are presented in this chapter. Procedures for testing the hypothesis are explained, and tables illustrating analysis of the data are included. Analyses of the data yield the following results.

Results

Data Description

Before making a detailed analysis of specific factors related to the individual force curves and velocity curves, it was necessary to examine the particular traits of these curves. Example recordings of timing marks and force and velocity curves up to 20 meter are presented in Figure 5.

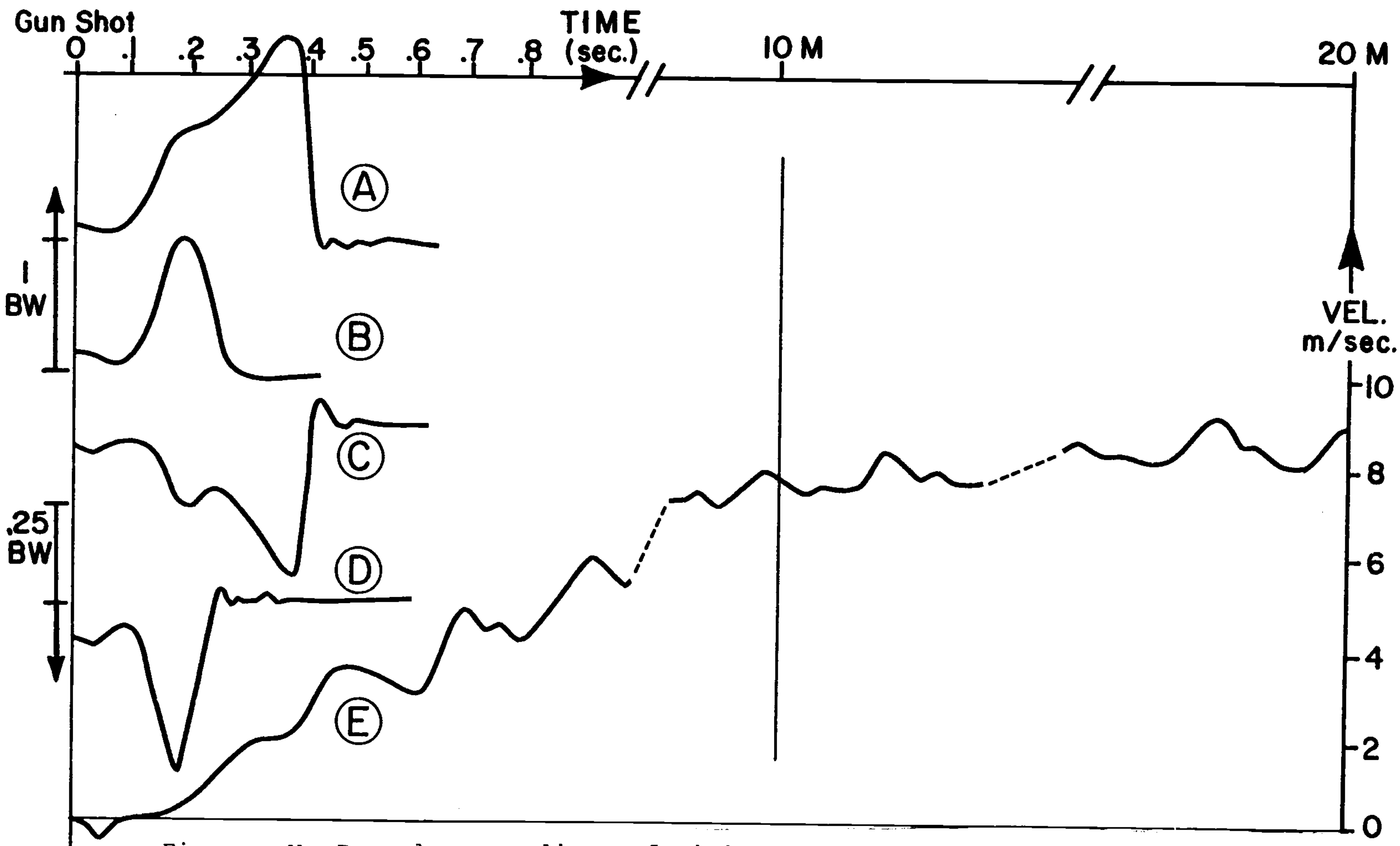

Figure V. Example recordings of timing marks and forces and velocity curves and timing mark.

As the shape of the curves were very similar for the twelve experimental starts, only the curves of position one (P1) were illustrated. Both feet started to exert force at the same time, but because of the longer duration of force application, the front leg contributed much more force than the rear leg. Force generated as obtained from recording paper were divided by per cent of body weight to obtain relative force values. Relative force value were applied in force analysis.

Statistical Analysis

A statistical model as indicated below was used to test analysis of variance subjects by treatments design.

$$Y = \mu + \alpha_i + \tau_j + \varepsilon_{ij}$$

μ : overall mean

α_i : the effects of ith subject, i = 1 to 5

τ_j : the effects of jth treatment, j = 1 to 12

ε_{ij} : the random error

Hypothesis 1: No significant difference would exist in time from start to the first 10 meters and to the second 10 meters among combinations of block angle and lateral block spacing.

Hypothesis 1.1: No significant difference would exist in time from start to the first 10 meters among combinations of block angle and lateral block spacing.

The analysis of variance results appear in Table 4.

As shown in Table 4, three combinations of block angles and lateral block spacings were significantly different. They are combined cases of 10 and 4 inches lateral block spacings and six front and rear block angles, combined cases of 4 inches lateral block spacings and six front and rear block angles, and combined cases of 10 and 4 inches lateral block spacings and 52.5 front block and all rear block angles.

Hypothesis 1.1, no difference in time to the first 10 meters due to block angles and lateral block spacings, was rejected on bases of the significant F values.

Hypothesis 1.2: No significant difference would exist in time from start to the second 10 meters among combinations of block angles and lateral block spacings.

The analysis of variance results appear in Table 5.

Table 4. Comparison of differences among treatments in time over the first 10 meters interval resulting from alteration in block angles and lateral block spacings

COMBINATION			TREATMENT		ERROR		F-RATIO
LS	FBA	RBA	DF	MEAN SQUARE	DF	MEAN SQUARE	
ALL	ALL	ALL	11	.0055	44	.0025	2.235 *
4	ALL	ALL	5	.0027	20	.0008	3.568 *
10	ALL	ALL	5	.0078	20	.0042	1.861
ALL	ALL	60	5	.0050	20	.0034	1.444
ALL	ALL	80	5	.0005	20	.0012	0.440
ALL	52.5	ALL	3	.0116	12	.0029	3.955 *
ALL	65	ALL	3	.0068	12	.0039	1.765
ALL	75	ALL	3	.0005	12	.0010	0.500

* Statistical significance at p>= .05.

Table 5. Comparison of differences among treatments in time over the second 10 meters interval resulting from combinations of block angles and lateral block spacings

COMBINATION			TREATMENT		ERROR		F-RATIO
Lat.Spa.	Front	Rear	DF	MEAN SQUARE	DF	MEAN SQUARE	
ALL	ALL	ALL	11	.0010	44	.0011	0.952
4	ALL	ALL	5	.0012	20	.0005	0.236
10	ALL	ALL	5	.0016	20	.0018	0.865
ALL	ALL	60	5	.0017	20	.0016	1.030
ALL	ALL	80	5	.0001	20	.0004	0.235
ALL	52.5	ALL	3	.0018	12	.0014	1.346
ALL	65	ALL	3	.0017	12	.0015	1.086
ALL	75	ALL	3	.0001	12	.0004	0.246

No significant difference at $p \geq .05$

As shown in Table 5, no significant difference in time over the second 10 meters interval was found among trials resulting from alterations in block angles and lateral block spacings.

Hypothesis 1.2 was accepted on basis of no significant F values.

Duncan's new multiple range test was applied to the two combinations with more than one treatment. The results of this analysis are presented in Table 6 and 7.

As seen in Table 6, there is a significant difference between combination 1 and combinations 3 to 6. Otherwise there is no significant difference for lateral foot spacings 4 and 10 inches combined. In Table 7 a significant difference can be seen between combination 1 and 2, and all other combinations.

The same methods were applied to test Hypothesis 2.

Hypothesis 2: No significant difference would exist in time from start to the first 10 meters and the second 10 meters among subjects performing combinations of block angle and lateral block spacing.

Hypothesis 2.1: No significant difference would exist in time from start to the first 10 meters among subjects performing combinations of block angles and lateral block spacing.

Table 6. Duncan's new multiple range test among combinations of case ALL-ALL-ALL applied to the running time means of the first 10 meters from alteration of block angles lateral block spacings

COM1	COM2	COM3	COM6	COM5	COM4	Significance level of cor.
2.252	2.267	2.303	2.317	2.318	2.329	
======	======					
-	.016	.051	.064	.066	.076	R2 = .0490
	======	======				
-	-	.035	.049	.051	.062	R3 = .0515
		======	======	======	======	
-	-	-	.029	.012	.027	R4 = .0527
			======	======	======	
-	-	-	-	.002	.013	R5 = .0534
				======	======	
-	-	-	-	-	.002	R6 = .0540

Table 7. Duncan's new multiple range test among combinations of case 4-ALL-ALL applied to the running time means of the first 10 meters from alteration of block angles and lateral block spacings

COM1	COM2	COM3	COM5	COM6	COM4	Significance level of cor.
2.231	2.242	2.300	2.308	2.318	2.322	
======	======					
-	.011	.065	.077	.086	.091	R2 = .0451
-	-	.054	.066	.076	.080	R3 = .0464
		======	======	======	======	
-	-	-	.012	.021	.026	R4 = .0470
			======	======	======	
-	-	-	-	.009	.014	R5 = .0475
				======	======	
-	-	-	-	-	.006	R6 = .0475

The analysis of variance results differentiating among subjects appear in Table 8.

Hypothesis 2.1, no significant difference in time to the first 10 meters due to subjects performing alteration of block angles and lateral block spacing, was rejected on basis of significant F values.

Hypothesis 2.2: No significant difference would exist in time from start to the second 10 meters among subjects performing combinations of block angles and lateral block spacing.

The analysis of variance results for different subjects appear in Table 9.

Hypothesis 2.2, no significant difference in time to the second 10 meters due to subjects performing alteration in block angles and lateral block spacing was, rejected on basis of significant F values.

Duncan's new multiple range test was applied to all significant combinations differenciating among subjects. The results of the snalysis are presented in Table 10 and 11, and indicated that male and female subjects performed significantly different in all eight treatment combinations for both the first and the second 10 meters with high coincidence among these combinations.

Table 8. Comparison of differences in running time among subjects during the first 10 meters resulting from alteration of block angles and lateral block spacings

COMBINATION			TREATMENT		ERROR		F-RATIO
Lat.Spa.	Front	Rear	DF	MEAN SQUARE	DF	MEAN SQUARE	
ALL	ALL	ALL	4	.2122	44	.0025	84.88 *
4	ALL	ALL	4	.1101	20	.0008	143.20 *
10	ALL	ALL	4	.1046	20	.0042	24.89 *
ALL	ALL	60	4	.1255	20	.0034	36.65 *
ALL	ALL	80	4	.0911	20	.0012	78.50 *
ALL	52.5	ALL	4	.0847	12	.0029	28.95 *
ALL	65	ALL	4	.0685	12	.0039	17.70 *
ALL	75	ALL	4	.0630	12	.0010	65.16 *

* Significant at the .05 level.

Table 9. Comparison of differences in running time among subjects during the second 10 meters resulting from alteration of block angles and lateral block spacings

COMBINATION			TREATMENT		ERROR		F-RATIO
Lat.Spa.	Front	Rear	DF	MEAN SQUARE	DF	MEAN SQUARE	
ALL	ALL	ALL	4	.1154	44	.0005	104.6 *
4	ALL	ALL	4	.0525	20	.0011	101.7 *
10	ALL	ALL	4	.0633	20	.0004	35.1 *
ALL	ALL	60	4	.0541	20	.0017	32.7 *
ALL	ALL	80	4	.0633	20	.0004	168.7 *
ALL	52.5	ALL	4	.0340	12	.0014	24.8 *
ALL	65	ALL	4	.0478	12	.0015	31.0 *
ALL	75	ALL	4	.0360	12	.0004	101.4 *

* Significant at the .05 level.

Table 10. Duncan's new multiple range test of all different angle and block spacing combinations in respect to different subjects for the first 10 meters

COMBINATION			SUBJECTS				
Lat.Spa.	Front	Rear	Sub2	Sub3	Sub1	Sub4	Sub5
ALL	ALL	ALL				=====	=====
4	ALL	ALL				=====	=====
10	ALL	ALL	=====	=====		=====	=====
ALL	ALL	60	=====	=====	=====	=====	=====
ALL	ALL	80				=====	=====
ALL	52.5	ALL	=====	=====	=====	=====	=====
ALL	65	ALL	=====	=====	=====	=====	=====
ALL	75	ALL				=====	=====

Table 11. Duncan's new multiple range test of all different angle and block spacing combinations in respect to different subjects for the second 10 meters

COMBINATION			SUBJECTS				
Lat.Spa.	Front	Rear	Sub2	Sub3	Sub1	Sub4	Sub5
ALL	ALL	ALL				====	====
4	ALL	ALL	====	====	====	====	====
10	ALL	ALL				====	====
ALL	ALL	60	====	====	====	====	====
ALL	ALL	80					
ALL	52.5	ALL	====	====	====	====	====
ALL	65	ALL	====	====	====	====	====
ALL	75	ALL	====	====		====	====

Stepwise multiple regression and rank order correlation were applied to test Hypothesis 3.

Hypothesis 3: No significant difference in the rank order of the independent variables determined by forward selective stepwise multiple regression that would predict dependent variable time.

The mean and standard deviation of independent and dependent variables, and the analysis of results of stepwise multiple regression for combination ALL-52.5-ALL over the first 10 meters are presented in Table 12 and 13.

The mean and standard deviation of independent and dependent variables, and the analysis of results of stepwise multiple regression for combination 4-ALL-ALL over the first 10 meters appear in Table 14 and 15.

The mean and standard deviation of independent and dependent variables, and the analysis of results of stepwise multiple regression for combination ALL-ALL-ALL over the first 10 meters appear in Table 16 and 17.

The mean and standard deviation of independent and dependent variables, and analysis of results of stepwise multiple regression for combination ALL-ALL-ALL, 4-ALL-ALL, and ALL-52.5-ALL over the second 10 meters and the first 20 meters appear in Table 18-23.

Table 12. Mean and standard deviation of independent and dependent variables for combination ALL-52.5-ALL over the first 10 meters

VARIABLE		MEAN	STANDARD DEV	CASES
T10M	(sec.)	2.2907	.1467	20
T20M	(sec.)	1.3212	.0912	20
FF1P	(% BW.)	.7639	.1401	20
FF2P	(% BW.)	1.2109	.2135	20
FVF2P	(% BW.)	.9248	.1922	20
AF1P	(deg.)	52.1795	7.6799	20
AF2P	(deg.)	50.0015	5.8707	20
FRH	(% BW.)	.6801	.3110	20
FRV	(% BW.)	.6415	.2864	20
AR	(deg.)	44.0569	9.5082	20
AF1P2	($deg.^2$)	2778.7338	905.9453	20
AF2P2	($deg.^2$)	2532.8866	605.9096	20
AR2	($deg.^2$)	2026.8971	907.3994	20

Table 13. Comparison of difference of variables entered by forward selection method of multiple regression in combination ALL-52.5-ALL over the first 10 meters

COMBINATION L F R	VARIABLE	MULTIPLE R	R-SQUARE	F	P
	AF2P	.60	.36	10.31	.005
	AR	.71	.51	8.91	.002
	AF2P2	.80	.65	10.05	.001
	AR2	.83	.69	8.44	.001
ALL 52.5 ALL	FRV	.83	.69	6.51	.003
	FF1P	.83	.70	5.12	.007
	AF1P	.84	.70	4.14	.015
	AF1P2	.90	.81	6.04	.004
	FRH	.91	.84	6.04	.005

Table 14. Mean and standard deviation of independent and dependent variables for combination 4-ALL-ALL over the first 10 meters

VARIABLE		MEAN	STANDARD DEV	CASES
T10M	(sec.)	2.3093	.1272	30
T20M	(sec.)	1.3301	.0873	30
FF1P	(% BW.)	.7382	.2255	30
FF2P	(% BW.)	1.1358	.2333	30
FVF2P	(% BW.)	.7687	.2394	30
AF1P	(deg.)	44.0992	9.5582	30
AF2P	(deg.)	42.3374	9.0127	30
FRH	(% BW.)	.6586	.2269	30
FRV	(% BW.)	.5967	.2323	30
AR	(deg.)	41.7275	9.7359	30
AF1P2	($deg.^2$)	2033.0546	973.0564	30
AF2P2	($deg.^2$)	1870.9743	790.2427	30
AR2	($deg.^2$)	1832.8170	811.5208	30

Table 15. Comparison of difference of variables entered by forward selection method of multiple regression in combination 4-ALL-ALL over the first 10 meters

COMBINATION L	F	R	VARIABLE	MULTIPLE R	R-SQUARE	F	P
			FF2P	.60	.36	16.24	.000
			AF1P2	.63	.39	8.96	.001
			AF1P	.67	.45	7.25	.001
			FRH	.72	.52	6.88	.001
			FRV	.73	.54	5.79	.001
4	ALL	ALL	AR	.79	.63	6.61	.000
			AR2	.80	.64	5.63	.001
			AF2P2	.80	.64	4.86	.002
			AF2P	.82	.67	4.65	.002
			FF1P	.83	.69	4.25	.003
			FVF2P	.83	.69	3.70	.007

Table 16. Mean and standard deviation of independent and dependent variables for combination ALL-ALL-ALL over the first 10 meters

VARIABLE		MEAN	STANDARD DEV	CASES
T10M	(sec.)	2.2977	.1314	60
T20M	(sec.)	1.3229	.0940	60
FF1P	(% BW.)	.7149	.1784	60
FF2P	(% BW.)	1.1265	.2188	60
FVF2P	(% BW.)	.7693	.2220	60
AF1P	(deg.)	45.4225	8.3876	60
AF2P	(deg.)	42.7469	7.7955	60
FRH	(% BW.)	.6640	.2289	60
FRV	(% BW.)	.6125	.2379	60
AR	(deg.)	42.5030	8.6405	60
AF1P2	(deg.^{2})	2132.3851	829.5628	60
AF2P2	(deg.^{2})	1887.0539	674.5136	60
AR2	(deg.^{2})	1879.9195	758.3844	60

Table 17. Comparison of difference of variables entered by forward selection method of multiple regression in combination ALL-ALL-ALL over the first 10 meters

COMBINATION L	F	R	VARIABLE	MULTIPLE R	R-SQUARE	F	P
			FVF2P	.55	.30	25.57	.000
			FRV	.57	.33	14.10	.000
			FF1P	.61	.37	11.33	.000
			FRH	.62	.39	8.93	.000
ALL	ALL	ALL	AR2	.64	.41	7.75	.000
			AF1P2	.65	.42	6.62	.000
			FF2P	.65	.43	5.62	.000
			AF2P2	.66	.43	4.98	.000
			AF2P	.67	.44	4.52	.000
			AF1P	.67	.44	4.00	.000

Table 18. Comparison of difference of variables entered by forward selection method of multiple regression in combination ALL-52.5-ALL over the second 10 meters

COMBINATION L F R	VARIABLE	MULTIPLE R	R-SQUARE	F	P
	AF2P	.62	.39	11.59	.003
	FVF2P	.68	.47	7.63	.004
	AR	.73	.53	6.14	.006
ALL 52.5 ALL	FF2P	.78	.61	5.96	.004
	AR2	.78	.62	4.62	.011
	FF1P	.79	.63	3.72	.022
	AF2P2	.79	.63	3.03	.044

Table 19. Comparison of difference of variables entered by forward selection method of multiple regression in combination 4-ALL-ALL over the second 10 meters

COMBINATION			VARIABLE	MULTIPLE R	R-SQUARE	F	P
L	F	R					
			FF2P	.68	.46	24.09	.000
			FF1P	.70	.49	13.08	.000
			AF2P2	.71	.51	9.29	.000
4	ALL	ALL	FRH	.78	.61	6.24	.001
			FRV	.79	.62	5.26	.001
			AR	.81	.67	5.33	.001
			AR2	.82	.68	4.72	.002
			AF2P	.82	.68	4.14	.004
			AF1P2	.83	.68	3.62	.008

Table 20. Comparison of difference of variables entered by forward selection method of multiple regression in combination ALL-ALL-ALL over the second 10 meters

COMBINATION L	F	R	VARIABLE	MULTIPLE R	R-SQUARE	F	P
			FF2P	.60	.37	34.15	.000
			FF1P	.63	.39	18.92	.000
			FRV	.65	.42	13.66	.000
			AF2P2	.66	.43	10.64	.000
			FRH	.67	.45	8.87	.000
ALL	ALL	ALL	FVF2P	.68	.46	7.76	.000
			AR2	.69	.47	6.82	.000
			AF1P	.69	.48	5.97	.000
			AF1P2	.69	.48	5.30	.000
			AF2P	.70	.49	4.78	.000
			AR	.70	.49	4.31	.000

Table 21. Comparison of difference of variables entered by forward selection method of multiple regression in combination ALL-52.5-ALL over the first 20 meters

COMBINATION L	F	R	VARIABLE	MULTIPLE R	R-SQUARE	F	P
			AF2P	.62	.39	11.68	.003
			AR	.71	.51	9.10	.002
			AF2P2	.81	.66	10.47	.000
			AR2	.82	.68	8.23	.001
ALL	52.5	ALL	FF1P	.83	.68	6.23	.003
			AF1P	.83	.69	4.95	.008
			AF1P2	.85	.73	4.65	.010
			FRH	.90	.81	5.91	.004
			FRV	.91	.83	5.76	.006
			FVF2P	.92	.85	5.38	.009

Table 22. Comparison of difference of variables entered by forward selection method of multiple regression in combiation 4-ALL-ALL over the first 20 meters

COMBINATION L	F	R	VARIABLE	MULTIPLE R	R-SQUARE	F	P
			FF2P	.65	.42	20.68	.000
			AF2P2	.66	.44	10.98	.000
			AF2P	.73	.53	9.91	.000
			AR	.75	.56	8.26	.000
			AR2	.76	.59	6.94	.000
4	ALL	ALL	FVF2P	.77	.59	5.72	.001
			FRH	.77	.60	4.81	.002
			FRV	.83	.69	5.91	.001
			FF1P	.83	.70	5.22	.001
			AF1P2	.83	.70	4.48	.002
			AF1P	.84	.71	4.03	.004

Table 23. Comparison of difference of variables entered by forward selection method of multiple regression in combination ALL-ALL-ALL over the first 20 meters

COMBINATION			VARIABLE	MULTIPLE R	R-SQUARE	F	P
L	F	R					
			FF2P	.58	.34	30.31	.000
			AF2P2	.61	.37	16.88	.000
			FVF2P	.63	.39	12.38	.000
			AR	.64	.41	9.83	.000
			AR2	.66	.43	8.44	.000
ALL	ALL	ALL	AF2P	.68	.46	7.66	.000
			FF1P	.68	.47	6.59	.000
			FRV	.69	.47	5.79	.000
			FRH	.69	.48	5.16	.000
			AF1P	.69	.48	4.63	.000
			AF1P2	.69	.48	4.15	.000

The ranked order of the independent variables, as given by the stepwise multiple regression and shown in Table 17-21, served as input to the rank order correlation test. The test was performed with the running time over the first 10, the second 10 and the first 20 meters respectively as dependent variable.

The results of rank order correlation with order established by stepwise foreward selection multiple regression are given in Table 24 - 26.

A value of 0.58, obtained from rank order correlation tables, served as level of significance at 10 degrees of freedom.

Small obtained values of R for all cases indicated no significant correlation among independent variables for the three examined block angles and lateral block spacing combinations.

Hypothesis 3, no significant difference in the rank order of the independent variables determined by forward selective stepwise multiple regression, was rejected on the basis of rank order correlation.

Table 24. Computation of the correlation coefficient from ranks assigned to 11 independent variables by three treatment combinations for a running time over the first 10 meters

Independent variable	ALL 52.5 ALL	4 ALL ALL	ALL ALL ALL	Sum of ranks	Square
FF1P	6	10	3	19	361
FF2P	* 11	1	7	19	361
FVF2P	* 11	11	1	23	529
AF1P	7	3	10	20	400
AF2P	1	9	9	19	361
FRH	9	4	4	17	289
FRV	5	5	2	12	144
AR	2	6	* 11	19	361
AF1P2	8	2	6	16	256
AF2P2	3	8	8	19	361
AR2	4	7	5	16	256
				199	3679

W = .08 R = .12

W : coefficient of concordance

R : rank order correlation

* 11: assumed rank which did'nt show up in the significant range

Table 25. Computation of the correlation coefficient from ranks assigned to 11 independent variables by three treatment combinations for a running time over the second 10 meters

Independent variable	ALL 52.5 ALL	4 ALL ALL	ALL ALL ALL	Sum of ranks	Square
FF1P	6	2	2	10	100
FF2P	4	1	1	6	36
FVF2P	2	4	6	12	144
AF1P	* 11	10	8	29	841
AF2P	1	5	10	16	256
FRH	* 11	6	5	22	484
FRV	* 11	7	3	21	441
AR	3	8	11	22	484
AF1P2	* 11	11	9	31	961
AF2P2	7	3	4	14	196
AR2	5	9	7	21	441
				204	4384

W = .61 R = .41

W : coefficient of concordance

R : rank order correlation

* 11: assumed rank which did'nt show up in the significant range

Table 26. Computation of the correlation coefficient from ranks assigned to 11 independent variables by three treatment combinations for a running time over the first 20 meters

Independent variable	ALL 52.5 ALL	4 ALL ALL	ALL ALL ALL	Sum of ranks	Square
FF1P	5	9	7	21	441
FF2P	* 11	1	1	13	169
FVF2P	10	6	3	19	361
AF1P	6	11	10	27	729
AF2P	1	3	6	10	100
FRH	8	7	9	24	576
FRV	9	8	8	25	625
AR	2	4	4	10	100
AF1P2	7	10	11	28	784
AF2P2	3	2	2	7	49
AR2	4	5	5	14	196
				198	4130

W = .57 R = .35

W : coefficient of concordance

R : rank order correlation

* 11: assumed rank which did'nt show up in the significant range

Discussion

Analysis of Variance (AOV)

Analysis of variance, subjects by treatment or treatment by subjects, is a statistical tool for determining difference between dependent and independent variables.

The basis of analysis of variance is the decomposition of variation of sums of squares corrected for the mean. The F-ratio serves as a test criterion for the significance of variation between the dependent variables, giving a statement about the usefulness of the given data.

In this study further evaluations in respect to different treatments had to be restricted to three significantly different data subsets, whereas all subsets in respect to different subjects were useful.

Duncan's New Multiple Range Test

For further evaluation of results of analysis of variance it might be not only necessary to know that the data indicates statistical significance but also to draw a conclusion about which factors are creating the significance. Duncan's new multiple range test served this objective. Duncan's new multiple range test determines significant difference between any two means in a set provided the range of each and every subset which contains the given means is significant according to a range test.

In this study underlined means showen in Table 6 and 7 are not significantly different. Disruption in the underlining is indicating significant difference among means to the left and right.

Stepwise Forward Selection Multiple Regression

Multiple regression is a very general statistical technique to analyze the relationship between a dependent or criterion variable and a set of independent or predictor variables.

The use of this technique as a descriptive tool is to find the best linear or curvelinear prediction equation and to evaluate its prediction accuracy.

Stepwise forward selection ensures that variables are entered in an order of highest respective contribution of the variable to the model of prediction. Therefore a rank order of significance of given variables is produced, which gives additional information about the proper parameters of the experimental design. It might also be helpful to eliminate less important variables from the model of prediction.

Rank Order Correlation Test

The rank order correlation test can serve as a criterion on statistical difference between two or more rankings resulting from different experimental parameters.

Interpretation of Data

The null hypotheses developed and tested in this investigation were formulated on the basis of the following questions:

(1) Is there a significant influence upon running time resulting from the starting block conditions ? How can an existing impact be estimated ?

(2) Is it possible to distinguish between sprinters of different levels of performance or other characteristic attributes ?

(3) Is it possible to predict the performance of a sprinter using only data about take off forces and resultant angles during sprint start ?

On the basis of the above questions, three null hypotheses were developed and tested for acceptance or rejection.

Analysis of variance applied to the running time over the first 10 meters provided a significant difference for three given data subsets. By employing Duncan's new multiple range test to two of these data subsets, angle combination front 52.5 and 65 with rear 60 degrees were the source of significant difference. This yields a rejection of hypothesis 1.

Analyzing the two groups of angle combinations resulting from Duncan's new multiple range test, similarities within them were found. The two combinations with a low front foot angle up to 65 degrees and a low rear foot block angle of 60 degrees combined distinguished themselves significantly from the other four combinations with either a high front foot angle or a high rear foot angle or both of them.

Analysis of variance applied to the running time over the first and second 10 meters showed a significant difference for every data subset.

By employing Duncan's new multiple range test to the data subsets, subjects 2 and 3 are significantly different in their performance from the other three subjects, as indicated in Table 2. This yields a rejection of Hypothesis 2. Two male subjects in this study were different from three female subjects.

Hypothesis 3, which involved stepwise multiple regression and rank order correlation test, was also rejected. The rank order correlation coefficients were at a low level, indicating no related rankings resulting from different angle and foot spacing combinations.

Refering to Table 24 for the case combining all different block angles and lateral block spacings, the second peak of front foot vertical force was ranked number 1. This shows the high importance of vertical force especially for the second strike of the front foot in the starting process.

This was demonstrated again by the second peak of the resultant force in the case of combining all different block angles and 4-inch lateral block spacing. The resultant force angle of this second peak of the front foot force is top ranked in the case of combining all different block angles and lateral block spacing with a front block angle of 52.5 degrees, completing this picture.

So angle and forces of the second peak of the front foot show the most impressive mechanical impact on the sprint start performance.

The first 5 steps of forward selection stepwise multiple regression analysis were summerized in frequency of appearance, and are presented in Table 27.

Table 27. Comparison of number of appearance of independent variables in stepwise multiple regression

INDEPENDENT VARIABLE	DEPENDENT VARIABLE T10M	T10M-20M	T20M	NUM. OF APPEARANCE
FF2P	10	11	11	32
FVF2P	10	10	7	27
FRH	9	7	9	25
FF1P	7	8	7	22
AF2P	5	9	7	21
FRV	8	6	7	21
AR	6	5	9	20
AR2	7	5	6	18
AF2P2	6	4	5	15
AF1P2	5	5	4	14
AF1P	4	5	2	11

As shown in Table 27, the results indicated that in eleven selected independent variables, FF2P contributed most to running time during the 20 meters sprint start. The second peak force contributed more than the first peak force, and both of them played an important role as independent variables to predict dependent variables. Vertical force of the second peak (FVF2P) gave more influence than horizontal force of the second peak.

Resultant force angle was not in a linear relationship with the dependent variable time, so higher order quadratic terms of resultant force angles were used to predict the chosen model, and better fitting was found.

CHAPTER V

SUMMARY

This chapter includes : (1) summary of the purpose and procedures of the study, (2) conclusion, and (3) recommendations.

Summary of the Study

This investigation compared the effects of two starting block variables on sprint performance. The variables investigated were the angles of the front and rear starting blocks and lateral block spacing. Sprint performance was measured in terms of time over 10 meters and 20 meters intervals, and the normal and tangential forces exerted on starting blocks.

Analysis of variance and Duncan's new multiple-range test were used to test Hypotheses 1 and 2 and forward selective stepwise multiple regression and rank order correlation test were used to test Hypothesis 3.

Analysis of the data established significant difference in running time over the first 10 meters as a result of alterations of block angles and lateral block spacings, but not at the second 10 meters. Combination of front 52.5 degrees, rear 60 degrees, combination of front 65 degrees, rear 60 degrees, and combination of front 75 degrees,rear 60 degrees, were significantly different from the remaining combinations. Therefore Hypothesis 1 was rejected. Significant differences among subjects were found not only in the first 10 meters but also in the second 10 meters. So, Hypothesis 2 was rejected. According to the results of rank order test, little concordance was shown between the ranking of independent variables among the three significant different treatment combinations. Therefore, Hypothesis 3 was rejected.

Conclusion

Significant difference did exist among treatment combinations of block angles and lateral block spacings of starting blocks which produced difference in running time. Significant difference did exist among subjects. Male subjects performed significantly different from female subjects. Significant differences did exist among the rank of independent variables which were used to predict the running time over the first 20 meters.

Limited number of subjects prevents specific identification, but supports additional study.

Recommendations

The outcome of this investigation suggests several possibilities for future research.

1. Enlarged subject size for different level trained sprinters could lead to more specific results.
2. Using only male or female subjects and comparing the different results might lead to the discovery of gender specific factors.
3. The statistical treatments used in this study would supply a meaningful research technique for further similar or related investigation in physical education.
4. Ultrasonic velocity measurement is strongly sugested for studying the characteristics of sprinting cycle relating to combination of block angle and lateral block spacing.

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