ANALYSIS OF LINEAR RUNNING VERSUS CURVE RUNNING AMONG FEMALE SPRINTERS

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We hereby recommend that the thesis prepared under our supervision by Ruth Vivienne Williams Simpson entitled "Analysis of Linear Running Versus Curve Running Among Female Sprinters."

be accepted as fulfilling this part of the requirements for the Degree of Master of Arts.

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Dedication

This research project is dedicated to my husband Wally, our daughter Shelly-Ann, and my sister Grace, for their loyal support and prayers throughout my educational endeavors.

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Chapter I

ORIENTATION TO THE STUDY

Introduction

A tremendous amount of progress has been made in women's sports since the beginning of the seventies. One possible reason may be due to the fact that women's role in society has changed greatly in the last decade. This change has been accompanied by a change in the public's attitude toward the woman who wishes to engage in sports. Nowhere is this trend more evident than in track and field.

It is startling to see that the literature on women in athletics include very little research on the female track and field athlete, in particular the sprinter. The female athlete has been participating in sports for many years, and with increasing intensity over the last two decades, but the majority of the researchers have chosen to favor their male counterparts.

In the Olympic Games and other international competitive events female athletes participating in track and field run distances ranging from 100 meters (m) through the 3,000 m. It was not until 1960 that women had the opportunity to run as far as 400 meters in the Olympics. In comparing the results of running events it would appear that the female athletes perform almost as well as the male competitors. Hoffman (1972) noted that, "after analyzing world records it appears that the achievement of female record holders represent ninety percent of the best male sprinters" (p. 1522). Hoffman postulated that this difference in achievement is probably due to a difference in muscle mass and skeletal size.

Of all the track and field events the short sprint is one of the most widely acclaimed, drawing intense interest from both competitors and spectators alike. The holder of the world's record and the Olympic Champion for the 100 m receive extreme adulation. However, the event is far more technical today than in former years when competitors were often able to win on natural talent and minimal training. Methods of improvement in starting, running form, speed and endurance have led to assaults upon records that were one time considered beyond reach.

The 100 m dash is divided into three phases: acceleration, maximum speed, and negative acceleration or deceleration (Schmolinsky, 1978, p. 122). Research has been done in these three areas in straight sprinting throughout the world, but comparatively little printed material is available. Much of the current concept in the United States regarding sprinting appears to be based upon early research. Henry (1952) reported that "most male sprinters reach peak velocity seconds after starting from blocks which varied only slightly despite the speed of the runner" (p. 35). Cornett (1976) in an unpublished thesis noted that "maximum velocity for women sprinters was reached at distances ranging from 30 to 50 m" (p. 69). The investigator noted that top rank women achieved maximum speed at an average of 5.05 secs., while sprinters with less ability achieved maximum speed at an average of 4.83 secs.

Sprinters over the years have been, described as good or poor curve runners, but no documented research has been conducted to ascertain the reason for efficiency or inefficiency of curve running. There is no published research available on the comparison of these categories in sprinting, yet the same individual most often runs two events: the 100 m on the straightaway; and the 200 m, the first 100 m being run on the curve. Furthermore, the 400 m relay, one of track's most popular events, is run with two legs, the first and the third being run on the curve.

It has long been noticed that certain outstanding runners on the straightaway have difficulty running the curve, while others who are less gifted make excellent curve runners on relays. This has given rise to the necessity for identifying sprinters who are better curve runners. Mitchell (1968), noted that:

> it is a general fact that big people being taller and having longer legs, take longer strides in walking and running than do shorter people. However, there is a serious problem with some athletes in negotiating the curve. This is especially evident with long legged runners (p. 1045).

Whether this is true or not, has yet to be ascertained. Taller runners seem to prefer the outside lanes where the curve is "less tight."

The problems arising in curve running may be different from those on the straightaway. Acceleration may take longer, maximum velocity may vary both in duration and degree, and negative acceleration may differ. Presently nothing is documented regarding the problems so essential to sprint success.

Results obtained from analyzing individual sprinters' weaknesses can provide the basis for individualized training. Hopefully, this study will prove to be useful by enabling track and field coaches to better understand the dynamics of curve running and, therefore, assist athletes in obtaining maximum performance in curve running as well as guiding the coaches in more effective selection procedures for relay runners.

Running continues to be a very popular recreational and competitive activity and improving performance is a topic for both researchers and participants. Track and field programs for women must be geared toward their abilities, therefore there is a need for the investigation of women in sprinting.

Statement of the Problem

The factors investigated in this research were those pertaining to efficient linear and curve running among female sprinters. Data were collected for nine female members of the Texas Woman's University track and field team to compare elapsed time on the straightaway and on the curve over a similar distance. The investigator looked at the differences between stride length on the curve and the straightaway, and the relationships between height and stride length, and leg length and stride length.

The experimental design required the use of photoelectric cells and an electric timer. Data were collected on selected sprinters as each one ran the 100 m dash. Each subject ran on the straightaway on the first day and on the curve on the second day. An analysis of the data was done to determine the following: (1) the differences between elapsed time on the straightaway and the curve, (2) the differences between stride length on the curve and the straightaway, (3) relationship between leg length and stride length and the relationship between height and stride length. Stride length was measured between the 40 and 70 m segments of the 100 m dash. This was done by measuring the imprint from touch-down of the left foot to touch-down of the right foot. The investigation was conducted in May 1981, at the Texas Woman's University.

Purpose of the Study

The primary purpose of this investigation was to compare the total elapsed time of trained athletes running similar distances on the straightaway and on the curve. A secondary purpose was to determine what made a difference in the running of curves as opposed to the straightaway.

Hypotheses of the Study

The specific purpose of this investigation was to test the following hypotheses at the .05 level of significance:

1. There is no significant difference between the elapsed time for running a specific distance on the curve and on the straightaway.
2. There is no significant difference in stride length while running on the curve and the straightaway.
3. There is no significant relationship between height and stride length.

4. There is no significant relationship between leg length and stride length.

Definitions and/or explanations of terms

The terminology used in this study is in keeping with research conducted in track and field both in this country and abroad, however certain terms defined below may have slightly different connotations when used properly in the physical and biomechanical sense.

For the purpose of clarification the following definitions and/or explanations were established throughout the study.

1. Electric Timer:

   The timing device which was used is an electric timer developed by Electronic Ideals Inc., of Denton, Texas. It consisted of eight digital clocks all of which were started simultaneously with a starting stimulus. The first digital clock measured the time as each subject ran the 100 m dash from the start to the 20 m mark, and each digital clock, in turn, registered the time at the 20, 40, 70, 90, and 100 m mark.

2. Maximum Velocity:

   The investigator accepted the definition of Bunn (1972), who stated that "maximum velocity is the maximum distance covered per unit of time" (p. 27).

For the purpose of this investigation "maximum velocity" was reported in meters per second; this was computed by dividing distance covered by time elapsed.

3. Acceleration:

The term acceleration refers to the "rate with which a body increases its velocity" (Hinson, 1977, p. 241).

4. Negative Acceleration:

The term negative acceleration refers to the rate with which a body decreases its velocity. This is commonly called "deceleration."

5. Stride Length:

"Stride length is defined as a cycle of motion which starts when one foot strikes the ground. The cycle may be designated a right stride or a left stride" (Slocum & James, 1968, p. 97). The investigator referred to stride length as the horizontal distance while sprinting, as measured between the spot of contact with the ground, from the heel of the right foot and the heel of the left foot.

6. Stride Frequency:

The investigator referred to stride frequency as the leg speed determined by strides per second.

7. Curve Running:

Curve running is defined as the movement of the body along a curved but not a circular path. For the purpose of this investigation curved running was referred to as running the curved section of a regular 400 m track.

8. Straightaway Running:

The investigator referred to straightaway running as the movement of the body in a horizontal direction on the straight of a regular 400 m track.

Delimitations of the Study

The research project was delimited to the following manner.

1. The 9 female members of the Texas Woman's University track and field team who participated in the study.
2. The cooperation of the 9 athletes who were subjects in the study.
3. Timing of the straightaway and the curve were done on two separate days, and in a constant order.
4. The degree to which environmental conditions remained constant.

Chapter II

Review of Related Literature

The first published research related to the analysis of the various phases of the sprint was done by Hill in 1927. He found that during his study of Cornell track men the velocity increased during a dash from zero at the start to a maximum speed at about 60 yards. He constructed an electric timer which would time runners through specified intervals of the race instead of through the entire course. The apparatus used was made up of a series of coils placed parallel to the track, accurately at 1, 3, 6, 10, 15, 20, 30, 40, 50, and 60 yards respectively. The coils were made up of copper wire which were connected to a moving-coil galvanometer placed in a pavillion. The movements were recorded on moving bromide paper in a camera of the type constructed by the Cambridge Instrument Company, and commonly used with the electrocardiograph. Each runner carried a thin magnet around his waist or chest, in this case, a hack-saw blade with its teeth ground off and magnetized in solenoid. The magnet induced a current in the coil each time the runner passed. This was recorded on the bromide paper in the camera.

Each subject ran four times during the same afternoon on a board track at 15 minute intervals. The results showed that the average difference between the mean and the time attained for any distance was only .014 sec. All ten men tested showed a decline in speed toward the end of the distance.

Hill discovered that maximum velocity occurred at about 60 yards, when accelerating from zero velocity. He believed that "in a short race an athlete was regarded as being propelled by a constant force proportional to his speed" (p. 51). It was discovered that an athlete attained a certain limiting speed rapidly, and was met with resistance mainly from within the body itself. This resistance was believed to have been initiated by the muscles.

Henry et al. (1951), attempted to validate the theoretical curve of sprint running in a two-component form consisting primarily of acceleration and velocity. A timing device was used to determine zero time defined as the instant the runner began to exert force against the blocks in response to the starting stimulus. Reaction time was defined as the period between the starting signal and the beginning of muscular movement. This was not recorded in the time scores measured.

Each subject's longitudinal spacing of the blocks was 18 inches, which had been established in the laboratory to be near the optimal for the runners. Permission was given to each runner to use either foot forward according to his individual predilection. Timing systems were set up at five yard intervals with adequate space beyond the 50 yard mark for each runner to slow down.

Subjects for the study were 25 men who were students in the regular physical education program. The average height was 5'9", and the average weight was 176.5 lbs. Ages ranged between 22 and 31 years. All the subjects were physically active but none had experience in track competition. They were given a number of practice starts after which a few sub-maximal trial runs were made separated by a 15 minute interval, this seemed to be adequate as the mean time of the second run was less than .01 sec. slower than the first.

The results indicated that the velocity constant (acceleration) was an important determiner of speed for the first five or ten yards, while maximum velocity was the key factor at all distances greater than five yards, and the only important factor after 20 yards. Both factors were required to predict speed for very short runs, although the single factor of maximum velocity was sufficient for dashes of 30 to 50 yards or longer.

Hoffman (1971), conducted a study on stature, leg length and stride frequency; it was concluded that the leg length is more connected with the athlete's running ability than his height. The purpose of this study was to find the best relationship between the length and frequency of a sprinter's strides, taking into account the length of his legs. The number of sprinters measured were 37 members of the Polish athletic team and 19 sprinters from other nations. The subjects were all males. The stature and the length of the legs were measured with a Martin Anthropometer. Measurement was done from the greater trochanter to the ground. Measurements for stride length and frequency were carried out exclusively during competition. The four elements of the stride taken include: (a) the maximum length of the stride (the average of four steps) from the starting line, (b) the average length of the strides and the number of strides (calculated from film), (c) the actual time taken during competition, recorded by stop watches, and (d) the average stride frequency. The stride frequency was calculated by dividing the number of strides by the time taken in the race with the corresponding correction for the last stride before the finishing line.

The data showed that the shortest athlete was 1.57 m in height, whereas the tallest measured 1.89 m. The longest leg measured was 100.5 cm, while the shortest measured 96.0 cm. Maximum stride length was 237 cm. Hoffman concluded that stride frequency did not show any great difference between the sprinters, and stride length remained identical with the same sprinters throughout the course of the year. Hoffman made the following conclusions:

> 1. Between height and leg length in one case and between length and frequency of stride in another, a distinct relation can be established with leading sprinters. The leg length is connected more with an athlete's running ability than his height.
>
> 2. Stride frequency does not show any great difference except in the willowy-type sprinters having weaker flexor muscles in the legs and trunk and in the case of the better runners versus the poorer runners in the lower category.
>
> 3. While stride length remains identical with the same sprinters in the course of the same year, the greatest stride frequency is reached in competition in the course of which the sprinter has gained his best time (p. 1469).

Hoffman (1972), studied stride length and frequency of female sprinters to determine how these influenced the elements of speed. The purpose of this study was to show how stride length and frequency of stride, along with other elements such as body composition and muscle mass influenced the achievement of speed among female sprinters. The investigation involved 23 females which included many of the world's best sprinters. Among the group were: Wilma Rudolph, Edith McGuire and Wyomia Tyus of the United States; Dorothy Hyman of Great Britian; Jutta Heine of West Germany; Giuseppina Leone of Italy; and Irena Krizenstein Szewinska and Eva Klobukowska of Poland. The range of their achievement in the 100 m was 11.00 to 12.0 sec.

All observations and measurements were carried out during top class competitions. Data were collected with a movie camera, which served as a stride counter. The lower limb was measured from the point of the greater trochanter to the ground. During the Polish championships, measurements were taken of four strides performed at full speed between the 50 m and the 60 m segment of the 100 m race. The time achieved and the total number of strides taken were used to estimate stride frequency. Two anthropometric measurements were taken to ascertain similarities among the top class sprinters; these were body height, and the length of the lower limb. Hoffman made the following conclusions:

> 1. It would appear that among superior female and male sprinters there is a strong correlation between height and leg length and frequency of stride.
>
> 2. There is a greater relationship between stride length and stride frequency, with leg length than with height.
>
> 3. The measurements and observations conducted several times on the same competitors verify that the sprinters with the shortest stature possess the highest frequency of stride.
>
> 4. In comparing the best female sprinters with their male counterparts, the former run however, about one second slower over the 100 m because of markedly lower frequencies of stride.
>
> 5. The above results were based on relatively limited sampling and still require verification from further research by measurement and observation (p. 1524).

Schmolinsky (1978), after a series of observations on male sprinters, reported that speed is a function of stride length and stride frequency. The athlete who wishes to improve speed will either take longer strides, stride faster or use a combination of both. The investigator reported that the curve of stride length has three definite phases: (1) a phase of high acceleration, (2) a relative constant phase, and (3) a phase of renewed acceleration. The duration of the first phase (high acceleration) was clearly dependent upon the runner's level of skill. Top class sprinters increased their stride length until 45 m was reached, whereas untrained runners reached the constant phase as early as 25 m. In all the sprinters studied an increase in stride length ended after 92 to 93 m. The greater stride length during the third stage (the last 3 or 4 strides) reflected the runner's attempt to counteract speed loss.

The stride frequency curve also indicated three phases; the phase of maximal acceleration, the phase of gradual deceleration, and the phase of greater deceleration.

Schmolinsky reported that the widely accepted notion that during performance of the 100 m dash the sprinter reaches the highest stride frequency during the first stride is wrong. There is a difference between the top level performers and the beginners relative to the point at which maximum speed was attained. Beginners attained maximum speed after as little as 10 to 15 m, whereas top class sprinters reached it after 25 m. The maximum speed curve of all runners was similar during the second stage; however, top performers showed the least decrease in frequency. During the third phase the greatest decrease in frequency appears between 90 to 95 m. The investigator reported that this was related to the lengthening of the strides over the last distance to be run.

Schmolinsky reported that the variation in speed in the 100 m dash can also be subdivided into three phases: the acceleration, the maximum speed, and the deceleration. In running the 100 m sprints speed increased to the maximum followed by a slight slow down. The differences between the speed curve of experienced runners and less experienced runners was that the acceleration during the starting phase was more marked in top class sprinters. The top class performers were able to continue to accelerate when beginners had already attained maximum speed.

There was also a variation in the distance to the stage of maximum speed. Beginners reached maximum speed at approximately 20 m while the more experienced runners accelerated until they attained maximum speed at 45 m and beyond.

Teradus (1964), used 19 undergraduate students from Los Angeles State College as subjects in a study of factors related to the change in sprinting velocity of college men. The purpose of this study was to determine the distance college men could sprint at maximum velocity. The investigator was under the assumption that acceleration is completed between 40 and 50 yards from the start of the run of the 100 yard, therefore leaving another 50 yards to be run at maximum velocity.

The subjects were enrolled in a general conditioning class. The class met twice a week for a period of 10 weeks. Students ranged in ages from 18 to 27 years, height varied from 5'8" to 6'4", and weight varied between 135 lbs to 220 lbs. An 8 mm movie camera was used to do the timing for the study. The camera was focused on the 220 yards straightaway of a clay track. The first 200 yards of the track were divided into 10 yard intervals.

Each runner performed a preliminary 50 yard dash four times as an indicator of his speed. This time was checked against the runner's time at the 50 yard mark in the actual run in order to ascertain whether the runner was exerting full effort. To be valid, a run had to be sprinted for a minimum of 100 yards. The time at the 50 yard mark had to be within .20 sec. of the best 50 yard time obtained in the four preliminary 50 yards sprints.

The subjects warmed up fully for the actual run. The runners started from blocks which were adjusted to each runner's comfort. As each subject assumed the "set" position both the stopwatch and the camera started simultaneously with the runner who started on his own time. The camera was focused on the shadow of the runner throughout the entire run and was disengaged when the run was finished. Each subject had to run on three occasions.

The results indicated that: (1) mean distance during which the subjects accelerated; first test 36.3 yards, second test 35.0 yards, and third test 31.3 yards. (2) For test one, two and three the mean distances which could be sprinted at maximum velocity was 50 yards, 51.3 yards, and 56.3 yards respectively. (3) The total distance run before deceleration was 86.3 yards for the first two tests and 87.5 yards for the third test. Maximum velocity was maintained for a mean distance of 52.5 yards, while mean deceleration upon reaching 100 yards was 5.4 percent of the mean maximum velocity.

The investigator concluded that male college students could sprint at maximum velocity for approximately 50 yards.

Selected biomechanical factors for college women running at maximum and submaximal speed was the subject of the study conducted by Teeple (1968). The subjects for this investigation were 28 female students enrolled in a physical education program at Pennsylvania State University. Their ages ranged between 18 and 22 years, height from 60 to 70 inches and weight from 107 to 158 lbs.

The specific biomechanical factors studied were angle of take-off, angle of leg lift, angle of touch-down, horizontal velocity, stride length, stride rate, time of support and non-support, and angle of trunk lean. In addition, the relationship between maximum running speed and height, weight, leg length, shoulder width, hip width, ankle width, and percent body fat were investigated.

Data were collected from three selected frames of three timed trials for each subject, including one maximum and two submaximum runs, all done on the same day. In addition the anthropometric measures of standing height in inches, weight in pounds, right and left leg length in centimeters, shoulder, hip, and ankle width in centimeters, and suprailiac and triceps skinfold also in centimeters. The filming was done with the use of a 16 mm electrically driven camera positioned 56 feet from the side of a running mat in a gymnasium.

Statistical analysis revealed the following results:

1. A significant negative correlation ($r = -.751$) exists between percent body fat and maximum running velocity. There were no other significant correlations obtained between running ability and anthropometric measures.
2. At the slower of the two submaximum running speeds the time of support, the time of non-support, and the angle of touch-down were correlated with maximum running velocity at a statistically significant level ($r = .851$).
3. At the intermediate running speed only time of support was found to have a statistically significant relationship with maximum running velocity ($r = .930$).
4. At the maximum running condition there were significant correlations between stride length and maximum running velocity ($r = .930$). There were no other significant correlations between running ability and mechanical factors.

5. Changes in running speed resulted in significant differences in six of the biomechanical factors including velocity, stride rate, stride length, time of support, time of non-support and angle of leg lift. The three remaining biomechanical factors showed no significant difference with the variables with which they were measured. This included angle of touch-down, for which there were no significant differences between the two paced speeds, and the angle of trunk lean and take-off for which there was no significant difference between any of the speed means.

The investigator drew the following conclusions:

1. The time of support was the primary biomechanical factor associated with running ability.
2. The factors which were significantly altered by changes in running speeds were stride rate, stride length, angle of leg lift, and time of support.

Eight male adults served as subjects in an investigation by Hoshikawa et al. (1973), the purpose of which was to analyze the running patterns of various runners, as adapted to progressive changes of speed. One of the subjects was an Olympian, who competed in the 400 m in the 1964 Olympic Games. He was classified by the investigators as an excellent runner. Three were inexperienced runners rated poor by the investigators, and the others were classified as average runners.

The subjects were tested at seven different speeds on a treadmill ranging from 200 m/min to 500 m/min with speed changes of 50 m/min. The pressure exerted by a foot was recorded on a special transducer developed for this purpose. A swing phase time, a support phase time and a stride phase time were measured. As the speed increased those phase times were reduced with the support phase time showing the greatest reduction. Rotary of the swing to the support phase time was approximately 0.2 at 500 m min. The time for one stride of the excellent runner was longer than that for the poor runners at every speed. Step length and step frequency were calculated with the results appearing on page 25. The investigators concluded that there is a difference in the leg movement of the excellent runner and of the poor runners even at the lower speeds.

Saito et al. (1974), attempted to analyze "the temporal pattern of rotary actions in the leg in relation to running speed" (p. 106). Three trained runners and an untrained man who had no special training in running served as subjects for this investigation. Each subject

Results of the investigation done by Hoshikawa et al.

Runners	Treadmill Speed m min.	Step Frequency per min.	Step Length in cm.
Poor	200	190	100
	250	200	125
	300	210	145
	350	220	155
	400	240	155
Average	200	170	120
	250	180	130
	300	190	150
	350	205	160
	400	230	165
Excellent	200	160	125
	250	165	150
	300	170	175
	350	180	190
	400	200	200
	450	210	200
	500	240	200

ran 70 m on a regular track at as near a constant speed as was possible without assistance. Ten trials were performed by each subject at various speeds from 4m/sec. to his maximum pace.

The rotary action of the hip, knee, and ankle joint were measured with electrogoiniometers. Foot timing information was obtained through the use of microswitches secured to the ball and heel of the shoe. The data were recorded on a visigraph by means of telemetry. The interval of footprints on the ground was used to determine step length. The progressive speed was calculated from the step length and the step frequency.

The investigators concluded that the step was lengthened with an increase in running speed of up to 7.0 m/sec. for the trained runners and 5.5 m sec. for the untrained, while the step frequency increased over that speed. There was a distinct difference in the length frequency curve between the trained runners and the untrained runners. This difference was especially noticeable in the step length, with a maximal length of 5'8" for the untrained and 6'8" to 7'7" for the trained runners.

The results of the above investigation indicated that the trained runner flexes his hip joint earlier after kicking as well as extending his knee joint earlier in the swing phase than the untrained runner. It is believed that the force produced by this extension adds to the kicking force exerted by the other leg. Therefore, the investigators suggested that hip flexion and knee extension should be done earlier to produce faster running. It was postulated that the trained runner extends his joint later after peak flexion than does the untrained. This was considered an indication that the trained runner is better able to keep his body in the air long enough to make full use of the forward component of the driving force in the performance of a longer step. The investigators suggested that it is therefore possible for the trained runner to increase his running speed by extending his hip.

Cornett (1976), conducted a study to investigate maximum speed of movement among female sprinters. The specific factors investigated were (a) the point in time and distance at which maximum velocity was attained and (b) the factors of leg speed and stride length which were thought to influence the attainment and maintenance of maximum velocity. The subjects were eight female members of the Texas Woman's University track team. Three were Olympians, two were members of the national track team,and the remaining were skilled but not national caliber sprinters. Data were collected as the sprinters ran the 100 m dash. The subjects started from the starting blocks and were timed using photoelectric cells and an electric timer as they performed the run. Film data were collected for each individual's performance. The study was carried out at the Texas Woman's University just prior to the national championships and Olympic trials in 1976 when the athletes ran their best times of the year. Although this study was done at the height of the athletes' conditioning, a one second difference was noted in each of the subject's best times when compared to their actual 100 m dash time which was run within a two week period of the testing.

Cornett reported the following results: (a) the average point in time at which maximum velocity was attained was 4.96 secs., and the average point in distance was 32.50 m. For the five superior athletes the average time was 4.83 secs. (b) The average time for which maximum velocity was maintained was 1.54 secs., and the average distance was 34 m, whereas for the skilled performers the average was 1.55 secs., and the average distance was 30 m. (c) Acceleration comprised 38 percent of the total time of the 100 m dash.

The following conclusions were drawn by the investigator:

1. Maximum velocity was reached at a distance ranging from 30 to 50 m, and was held over a distance ranging from 10 to 20 m. Deceleration first occurred at varying points from the 50 m mark to the 70 m mark.

2. Maximum velocity involved a relatively small distance of the run, about 14%, acceleration involved about 33%, and deceleration involved almost 53% of the run.

3. As stride frequency decreased from its highest rate during the acceleration phase the increase in stride length more than compensated for the loss of leg speed during the maximum velocity phase (p. 69).

In reviewing the literature relevant to the study, this investigator also noted other findings related to the improvement of sprinting speed. Ozolin (1971), in an article on "how to improve speed", stated that "speed in its various forms should constantly improve with the athlete's training age" (p. 1400). Ozolin suggested that explosive speed can be developed in several ways. One of these is to introduce speed exercise under artifically created difficult situations, followed by the same exercise under normal conditions. He stated that maximum speed and movement frequency in running can be improved through the use of musical rhythm, such as that provided by the metronome. He believed that the gradually accelerating rhythm of the metronome will help the athlete improve his maximum speed. Speed barriers can be overcome by exercising under more favorable conditions. These exercises allow for speed and frequency in a time unit which is not possible under normal conditions. It is postulated that when an athlete performs repetitions of an "over fast" exercise, it provides the athlete with confidence that he can improve his existing speed, and it also leaves traces of the new speed in the neuro-muscular coordination system.

Soviet coach Fruktov noted similar developments with sprinters attached by an elastic rope to a motorcycle (Ozolin, 1971, p. 1401). A prominent sprinter raced behind the motorcycle for three repetitions over 50 m from the flyin start with a six minute rest interval between towing. After another rest period of six minutes he performed two more repetitions of 50 m from a flyin start under normal conditions and improved his best time by 0.3 sec.

Dintiman (1971), developed two programs for sprinting, sprint-assisted training and sprint-resisted training, to improve the rate and efficiency of leg movement per second and also to strengthen the muscles involved in the sprinting action.

Sprint-resisted training places the body under increased internal resistance through the use of incline running or weighted clothing; this attempts to stimulate the sprint action. Incline running can be done by training uphill. This was believed to increase the leg strength, knee lift, and cardiovascular-respiratory endurance. Staircase running is another method often used to improve leg strength. The author noted however, that incline training program should serve only as a supplement to flat surface training.

Strength training may be done in the form of weight training. Various types of isotonic, isometric, and isokinetic weight training are important in developing strength which is essential for such factors as explosiveness, acceleration, stride length improvement and the maintenance of maximum sprinting speed. Dintiman emphasized that flexibility exercises and flat surface striding should follow the use of any sprint-resisted program; this is necessary to eliminate the possibility of reduced stride length.

Sprint-assisted programs have been shown to improve the rate of leg movement per second. It would appear that this rate can be altered through the correct use of sprint training and supplementary training programs.

There are three specialized programs which attempt to achieve this: (1) downhill running, (2) towing and (3) treadmill running. These programs must be carefully implemented with the objective of an increased rate of leg movement per second achieved without any decrease in stride length.

Downhill running should be done early in the workout since leg movement per second is stressed. This form of training attempts to increase the rate of leg movement, develop speed, lengthen stride and improve relaxation (Dintiman, 1971, p. 148). Towing is performed most effectively with a pacing machine consisting of a tow bar and handle attached to the rear bumper of an automobile. Dintiman believed that treadmill running designed to gradually force an individual's rate of movement per second to a speed beyond that capable in unaided running will result in improved speed on a flat surface (Dintiman, 1971, p. 148).

The above programs were developed by Dintiman as well as the Russian program constructed for some of their prominent sprinters assumed that maximum velocity and speed endurance were not just inherited characteristics but were factors which could be developed.

The factors investigated in this study were specific to female sprinters, although research pertinent to and based upon male sprinters was also reviewed. The findings would indicate that the differences between the men and women studied are basically those of capacity and not necessarily those of technique.

Chapter III

Methods and Procedures

The purpose of this research project was to investigate selected variables that may affect the performance of female sprinters on the curve and the straightaway. Specifically it examined (1) the differences between elapsed time on the curve and the straightaway for 100 m, (2) the differences between selected segments of the 100 m for the straightaway and the curve, (3) the differences between stride length on the straightaway and the curve, (4) the relationship between stride length and leg length, and (5) the relationship between stride length and height. An explanation of the preliminary proceudres, selection and description of instruments used, selection of subjects and procedures related to the collection and analyses of data are presented in this chapter.

In gathering information both human and documentary sources were utilized. Documentary resources included available periodicals as well as unpublished material relevant to the study. The human resources included the sprinters, who were members of the Texas Woman's University track and field team, members of the thesis committee, track and field experts, and an experienced statistician.

Preliminary Procedures

In the preparation for the development of the proposed study the investigator assimilated information pertinent to all phases of the research project. A tentative outline of the proposed study was developed by the investigator and presented to the thesis committee. The outline was revised in accordance to suggestions offered by the thesis committee.

An outline of the proposed investigation was presented to the Human Subjects Review Committee who subsequently granted permission to conduct the research. Written permission was also secured from the subjects involved in the study. A prospectus of the proposed study was filed in the Office of the Provost of the Graduate School.

Selection and Description of the Instrument

The experimental instrumentation consisted of an electronic timer developed by Electronic Ideals, Inc. of Denton, Texas. This instrument is a multiple timing system consisting of eight digital clocks which provided a breakdown of times for the analysis of each sprinter at the specified distances of 20, 40, 70, 90, and 100 m. Eight photo-electric cells were mounted on 36 inch pedestals so that the eye of the cell was 37 inches high. An accompanying reflector was placed opposite each photo-electric cell at the corresponding height completing the timing gate. The distance between each photo-electric cell and reflector was 48 inches. Each photo-electric cell was connected to the timer.

The subjects used a standing flyin-start approximately 5 m back from the initial timing gate. This allows the subject to be in motion when the first timing gate was disrupted to begin the timing sequence. The first digital clock recorded time from the start to the 20 m mark, and each digital clock in turn recorded time at the 20, 40, 70, 90, and 100 m mark to the nearest one hundredth of a second. The instrument used for recording leg length and stride length was an ordinary measuring tape marked off in feet and inches and meters and centimeters. For recording height and weight a standard physician's scale with a device attached for height measurement was utilized.

The subjects for this investigation were 9 female members of the Texas Woman's University track and field team. They were informed as to the nature of the study by both their coach and the investigator. The subjects were a combination of sprinters, hurdlers and quarter milers. Four of the subjects were regarded as outstanding sprinters, as three were Olympians and one other had qualified for the National Championships. The remaining sprinters were excellent runners, but presently were not of national or international quality.

Collection of Data

Data were collected for 9 female sprinters using the electric timer and the photo-electric cells to determine differences in elapsed time on the straightaway and the curve. Stride length was measured to determine differences between (1) stride length on the curve and the straightaway, (2) relationship between stride length and leg length, and (3) relationship between stride length and height. Stride length was measured between the 40 and 70 m segments of the 100 m. This was done on both the straightaway and the curve. Measurements of height and leg length were obtained to determine relationship between height and stride length and leg length and stride length. Leg length was measured from the greater trochanter to the ground. This was obtained from the right leg. Data were collected on May 13, and 14, 1981, prior to the National Championships.

Each subject was encouraged to put forth her best effort so that the most valid results could be obtained. Subjects were given an adequate period to warm-up after which each individual ran the 100 m from a standing flyin start. On the first day of testing data were collected on the straightaway and on the second day data were obtained for the curve. To obtain measurement for stride length the designated section of the track was discolored by covering the area with flour so that the imprints of stride length were easily visible. The imprint from touch-down of the left foot to touch-down of the right foot was measured. This was repeated in order to obtain a two stride cycle and to allow for differences in bilateral stride. The subjects repeated their runs after a 20 minute rest interval.

The following procedures were followed in the analyzing of the data. The times of the intervals were obtained by using the data from the electric timer for each of the timed segments. In order to compare the different segments on the curve with the straightaway, velocity was calculated for each timed segment. The velocity was obtained by dividing the distance covered in each segment by elapsed time.

Stride rate for each subject was calculated in the following manner. The differences in the times of the 40 m and 70 m segments were divided by 30 (the distance of the interval) to determine meters per second. For example, time at the 40 m mark (4.60 secs.) was subtracted from time at the 70 m mark (7.85 secs.) which produced a time of 3.25 secs. for that interval which was divided by 30 meters. The resulting value expressed in meters per second was then divided by the stride length of one complete cycle (length from touch-down of the left foot to the right and touch-down of the right foot to the left). This yielded the number of cycles per second which was then multiplied by two to determine the number of strides per second or stride rate (Cornett, 1976, p. 39).

The statistical analyses of a paired t test, and a two factor repeated ANOVA were used to compare differences between elapsed times on the straightaway and times for the different portions between both locations. The statistical analysis of Rho was computed to determine correlation coefficients between selected variables. The Dec 20 computer system of the Texas Woman's University was used to compute all the data. These data are presented in Chapter IV.

Chapter IV

Presentation of the Data

Introduction

The data in this investigation were gathered through the use of an electric timer and photo-electric cells as the subjects ran the 100 m on both the straightaway and the curve of a regular 400 m track. The subjects were nine college age female runners who were members of the Texas Woman's University track team. The primary purpose of this research was to compare the total elapsed time of trained athletes running similar distances on the straightaway and on the curve. A secondary purpose of the study was to investigate certain factors that might have relationships between height and stride length and leg length and stride length for female athletes. This chapter is a presentation of these data in both narrative and tabular form.

Descriptive Information Regarding Subjects

Accumulation of the height and weight data of the subjects was done in inches and pounds, respectively. The investigator converted these findings to metric units to report height in inches and centimeters and weight in pounds and kilograms. Table 1 is a display of the height

Table 1

Descriptive Data of Subjects on the Variables

of Height and Weight

Subject	Height (in)	Height (cm)	Weight (lbs)	Weight (kg)
1	60"	152.4	100	45.45
2	65"	165.1	155	70.45
3	65"	165.1	125	65.90
4	64"	162.5	125	56.81
5	60"	152.4	100	45.45
6	61"	154.9	114	51.81
7	65"	165.1	133	60.45
8	71"	180.3	135	61.36
9	64"	162.5	135	61.36
M	65.05	164.89	127.11	57.70
SD	3.32	8.69	19.40	8.70

and weight of the subjects. An inspection of the table reveals that the subjects ranged in height from 60 in. (1.52 m) to 71 in. (1.80 m) with an average of 65 in. (1.64 m). The standard deviation for height was 3.32. The subjects were relatively homogenous in height.

The subjects ranged in weight from 100 lbs. (45.45 kg) to 155 lbs. (70.45 kg). The average weight was 127 lbs. (57.5 kg) and the standard deviation was 8.70. The subjects were less homogenous in weight than height.

Elapsed Times for Both the Straightaway and the Curve

The nine subjects were randomly arranged for performance for the collection of the data. The runners commenced their sprint from a standing flyin-start and started 5 m back from the initial timing mark. Each subject performed the 100 m twice and the better of the two trials was used for the analysis of the data. For the straightaway the subjects accumulated time ranged from 11.19 secs. to 13.09 secs., with an average of 12.10 secs. The accumulated time for the curve ranged from 11.24 secs. to 14.38 secs., with an average of 12.62 secs. These data appear in Table 2.

The data collected for elapsed times on the straightaway and the curve indicated that the fastest times for both locations were run by the same individual, with a

Table 2

Elapsed Times for both the Straightaway and the Curve

Subjects	Time on straightaway	Time on curve	Difference between straightaway and curve
1	11.19	11.24	.05
2	11.33	11.70	.37
3	11.31	11.40	.10
4	13.09	14.38	1.29
5	12.65	13.10	.45
6	12.05	12.85	.82
7	12.70	13.73	1.03
8	12.33	12.85	.52
9	12.25	12.36	.11
Mean	12.10	12.62	.52
SD	0.68	1.05	.43

minute time difference of .05 secs. Two other subjects, three and nine, also ran times for both the curve and the straightaway in which the time differentials were only .10 and .11 secs. One runner was an excellent performer while the other was considerably less skilled - nearly 1 sec. slower in the 100 m; however, both had little fall off in their curve time when compared to their straightaway time.

Another of the highly skilled subjects, number two, ran the curve .37 secs. slower than the straightaway which was comparatively slower than the previously mentioned subjects. For the most part, however, the less skilled the straightaway runner, the greater the amount of time lost on the curve - with the exception of subject nine previously mentioned. Whether the ability to maintain excellent performances on both the straightaway and the curve is related to greater movement efficiency is a matter of conjecture. The greater acceleration attained by the faster runners, if a result of greater movement efficiency, would also enable these runners to maintain their acceleration for a longer duration since an efficient runner is able to maintain the speed-endurance phase longer (Dintiman, 1971, p. 148).

The data in Table 2 revealed that although some very good times were run on the curve, no one turned in a faster time on the curve than the straightaway. This would indicate that only an unusual runner will run faster on the curve than on the straightaway. A good curve runner then is one who loses less time when running the curve than other runners of comparative speed.

In order to determine if a significant difference existed between elapsed times on the straightaway and the curve a paired _t_ test was computed. The results of this test appear in Table 3. The results indicated that there is a statistically significant difference between elapsed time on the straightaway and the curve. It should be noted that the level of significance obtained was better than .001.

Table 3

Results of Paired _t_ Test for Elapsed Time on the Straightaway and the Curve

Variable	_N_	_M_ (sec.)	_SD_ (sec.)	_SEM_ (sec.)	t*
Time on the straightaway	9	12.10	0.686	0.228	3.605**
Time on the curve	9	12.62	1.059	0.3530	

*t .05 $\overline{<}$ 1.860.

**p < .001 with 8 degrees of freedom.

Time Segments for the Subjects at 20, 40, 70, 90, and 100 m

The multiple timing system provided the times for an analysis of each individual sprinter at the specified distances of 20, 40, 70, 90, and 100 m, as each sprinter ran the 100 m course on the straightaway and also on the curve. These data along with their averages are presented in Table 4. A review of this table reveals that the average time for the first 20 m segment was 2.74 secs., 5.08 secs. to arrive at 40 m, 8.53 secs. for the 70 m, 10.96 secs. for the 90 m, and 12.10 secs. for the total 100 m.

An interesting observation was that most of the sprinters turned in times during testing that were close to their best performances. This could be attributed to the fact that they were all in excellent condition. However, each subject started with a 5 m standing flyin-start and was accelerating when she approached the first timing gate. This obviously is an advantage over a block start and doubtlessly contributed to some of the fast times recorded. Another noteworthy fact was that in most cases the best times at 20 m and 40 m were reflected in the superior times at 100 m.

A further review of Table 4 reveals the following averages for the curve: 20 m, 2.62 secs., 40 m, 5.02 secs.,

Table 4

Time Segments and Intervals for Both the Straightaway and the Curve

Subjects		0-20 M	20-40 M	INT	40-70 M	INT	70-90 M	INT	90-100 M	INT
1	S	2.49	4.60	2.11	7.85	3.25	10.07	2.22	11.19	1.12
	C	2.54	4.68	2.14	7.95	3.27	10.15	2.20	11.24	1.09
2	S	2.75	4.82	2.07	8.23	3.41	10.33	2.10	11.33	1.00
	C	2.63	4.84	2.21	8.19	3.35	10.60	2.41	11.70	1.10
3	S	2.76	4.86	2.10	8.14	3.28	10.29	2.15	11.31	1.02
	C	2.43	4.66	2.23	8.18	3.52	10.29	2.11	11.41	1.12
4	S	2.81	5.23	2.42	8.94	3.71	11.81	2.87	13.09	1.28
	C	2.62	5.17	2.55	9.00	3.83	12.73	3.73	14.38	1.65
5	S	2.78	5.27	2.49	8.89	3.62	11.40	2.51	12.68	1.28
	C	2.67	5.22	2.55	9.12	3.90	11.95	2.83	13.10	1.15
6	S	2.70	5.14	2.44	8.59	3.45	11.05	2.46	12.05	1.00
	C	2.48	4.82	2.34	8.40	3.58	11.75	3.35	12.85	1.10
7	S	2.85	5.53	2.68	8.99	3.46	11.50	2.51	12.70	1.20
	C	2.57	5.29	2.72	9.07	3.78	12.43	3.36	13.73	1.30
8	S	2.78	5.35	2.57	8.85	3.50	11.03	2.48	12.33	1.30
	C	2.80	5.60	2.80	90.17	3.57	11.61	2.44	12.85	1.24
9	S	2.78	4.98	2.20	8.40	3.42	11.19	2.79	12.25	1.06
	C	2.88	5.05	2.17	8.40	3.35	10.93	2.53	12.36	1.43
$\bar{X}$	S	2.74	5.08	2.34	8.53	3.45	10.96	2.45	12.10	1.14
	C	2.62	5.02	2.41	8.61	3.57	11.34	2.77	12.62	1.24

S = Straightaway; C = Curve; INT = Interval

70 m, 8.61 secs., 90 m, 11.34 secs., and 100 m, 12.62 secs. There was little difference between the curve and the straightaway in the elapsed time for the first three intervals. The first and second segments (0-20 m and 20 m - 40 m) favored the curve runners, 0.12 and 0.06 respectively.

The runners on the straightaway did not equal their curve performance until the third segment (40 m - 70 m) when the mean time difference favored the straightaway runners by .08 secs. It must be noted that the mean time differences between the straightaway and the curve runners began to increase noticeably at the 70 to 90 m (.38) segments with the faster time being run on the straightaway. This trend is even more apparent from 90 to 100 m. The difference for this 10 m segment is .52 seconds favoring the straightaway.

In order to compare movement time for the different intervals for both the curve and the straightaway the velocity was calculated for each segment of the run. These data are expressed in meters per second and are presented in Table 5. The more highly skilled performers attained higher velocities earlier and maintained their speed longer than did the less skilled performers. The

Table 5

Velocity at the 20, 40, 70, 90, and 100 m Segments for the Straightaway and the Curve (meters/sec)

Subjects		0-20 M	20-40 M	40-70 M	70-90 M	90-100 M
1	S	8.03	9.47	9.23	9.00	9.89
	C	7.87	9.34	9.47	9.09	9.17
2	S	7.27	9.66	8.79	9.52	10.00
	C	7.60	9.04	8.96	8.29	9.09
3	S	7.24	9.52	9.14	9.30	9.80
	C	8.23	8.96	8.52	9.47	8.92
4	S	7.11	8.26	8.08	6.96	7.81
	C	7.63	7.84	7.83	5.36	6.06
5	S	7.19	8.03	8.28	7.96	7.81
	C	7.49	7.84	7.69	7.06	8.69
6	S	7.40	8.19	8.69	8.13	10.00
	C	8.06	8.54	8.37	5.97	9.09
7	S	7.00	7.46	8.67	7.32	9.43
	C	7.78	7.35	7.93	7.90	7.69
8	S	7.19	7.78	8.67	8.06	7.69
	C	7.14	7.14	8.40	8.19	8.06
9	S	7.19	9.09	8.77	7.33	9.43
	C	6.94	9.21	8.95	7.90	6.99
$\overline{X}$	S	7.50	8.60	8.69	8.17	9.09
	C	7.70	8.36	8.45	7.69	8.19

S = Straightaway; C = Curve

mean maximum velocity occurred between 90-100 m with the next fastest velocity between 40 and 70 m.

In order to determine significant differences within the segments, a 2 factor repeated ANOVA was computed. These results appear in Table 6. This was done through the BMDP2V Analysis of Variance and Covariances with repeated measures, designed by the Health Sciences Computing Facility, University of California, Los Angeles. The results indicated significant differences for both the segments and the two conditions. These results also indicated non significant interaction between the segments and the conditions, and because of this a further analysis of main effect was computed. A Kruskall-Wallis analysis of variance of rank indicated a significant difference between the segments; the 0-20 m mark favored the curve while the remaining segments favored the straightaway ($X^2 = 8.36$, df - 1 $P < .05$).

Figure 1 is a graphical presentation of the subjects' mean velocity for the different portions of the 100 m run which was previously discussed. The average velocity for the 0-20 m segment with a flyin - start was 7.5 secs., on the straightaway and 7.70 secs. for the curve. During the 20-40 m segment of the run the average velocity was 8.60 secs., for the straightaway and 8.36 secs. for the

Table 6

Results of a Two Factor Repeated ANOVA

Source	SS	df	MS	F
Location	3.42225	1	3.42225	21.46*
Error	1.27598	8	0.15950	
Portion	13.89101	4	3.47275	5.77**
Error	19.25699	32	0.60177	
Location and Portion	4.19912	4	1.04978	2.26
Error	14.87080	32	0.46471	

*F .05 $\overline{<}$ 5.32

**F .05 $\overline{<}$ 2.69

*p < .001 with 8 degrees of freedom

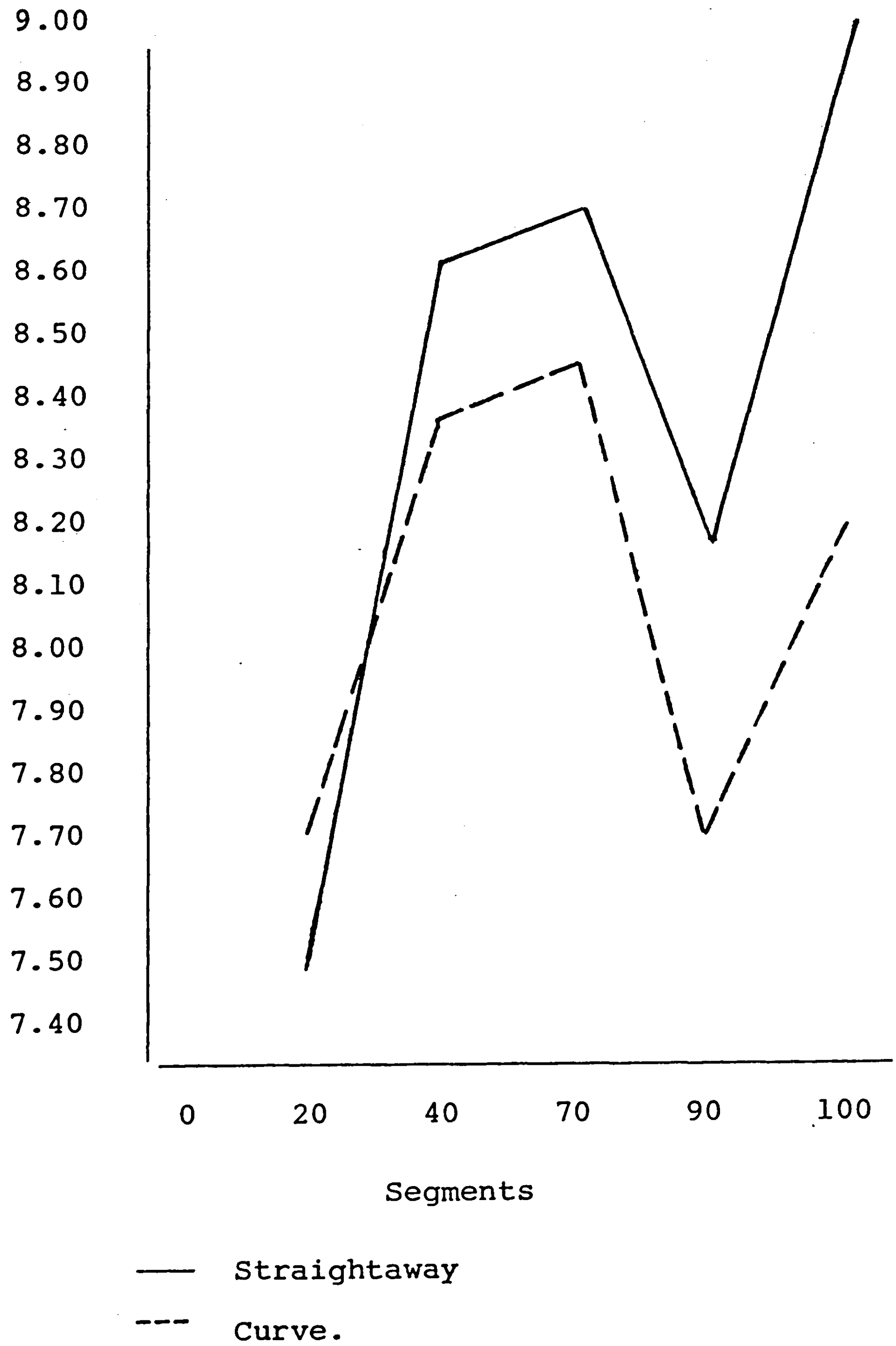
**p < .001 with 32 degrees of freedom

Location = straightaway

Portion = curve

Figure 1

Mean Velocity on the Straightaway and the Curve



curve. The average velocity for the 40-70 m segment was 8.69 secs. for the straightaway and 8.45 secs. for the curve. The average velocity attained during the 70-90 m segment of the run was 8.17 secs., and 7.69 secs. for the straightaway and the curve respectively. The average velocity attained for the 80-100 m segment of the run was 9.09 secs. for the straightaway and 8.19 for the curve.

The buildup of velocity through the first segments was as expected. However, an unexpected finding occurred with the runners achieving a faster time on the first segment of the curve than the straightaway. This was reversed during the subsequent segments. Deceleration occurred after 70 meters but the last 10 meters found an increase in the mean velocity of all subjects on both the curve and the straightaway. Normal deceleration did not occur over the last 10 meters as found in Cornett's study (Cornett, 1976, p. 55). This tendency was even more noticeable on the straight than the curve.

Descriptive Information Regarding Leg Length, Stride Length and Stride Rate

The data collected on height, leg length, and stride length have been gathered emperically to answer the following research questions: (a) what is the relationship between height and stride length, (b) what is the relationship between stride length and leg length, and (c) what are the differences between stride length on the curve and the straightaway.

Collection of the leg length and stride length data were done in feet and inches. However, the investigator converted these findings to metric units to report leg length in inches and centimeters, and stride length in feet and inches as well as centimeters. Table 7 is a presentation of the data on leg length.

In order to determine the relationship between height and stride length, and leg length and stride length, the statistical technique of Rho was utilized. The results indicated a significant correlation between height and stride length: $r = .583$ on the straightaway, and .582 on the curve ($p < .05$). The correlation between stride length and leg length indicated an even closer relationship, $r = .983$ on the straightaway, and .981 on the curve. This emphasizes the greater importance of leg length in relationship to stride length as compared to height and stride length.

Tables 8 and 9 represent the data collected for stride length during maximum speed. These measurements were obtained during the 40 to 70 m segments of the run. The results indicated that the longest stride length was

Table 7

Subjects Leg Length as Measured from the Greater Trochanter to the Ground

Subjects	Leg Length (in)	Leg Length (cm)
1	34	86.36
2	35	88.90
3	36	91.44
4	33	83.82
5	34	86.36
6	35	88.90
7	33.75	85.72
8	40	101.60
9	34	86.36
Mean	34.97	88.82
SD	2.07	5.27

Table 8

Stride Length on the Straightaway at Maximum Speed

Subjects		Stride Length (feet & in)	Stride Length (cm)
1	R-L	6' 11"	210.80
	L-R	6' 9"	205.70
2		7' 10"	238.70
		7' 5"	226.06
3		7' 9"	236.22
		7' 5"	226.06
4		6' 1"	185.42
		6' 6"	198.12
5		6' 2"	189.96
		6' 0"	182.88
6		7' 4"	223.52
		7' 2"	218.44
7		6' 6"	198.12
		6' 7-1/2"	201.93
8		7' 10"	238.70
		7' 8"	233.60
9		6' 0"	182.88
		6' 9"	205.74
M		6' 8"	211.59
		6' 9"	201.33
SD		0.73	23.39
		0.70	20.21

R-L=Right to left side.

L-R=Left to right side.

Table 9

Stride Length on the Curve at Maximum Speed

Subjects		Stride Length (feet & in)	Stride Length (cm)
1	R-L	7' 1"	215.90
	L-R	6' 7-1/2"	201.90
2		7' 8-1/2"	234.95
		7' 8-1/2"	234.95
3		7' 6"	228.60
		7' 4"	223.52
4		6' 4"	193.04
		6' 3"	190.50
5		6' 7"	200.66
		5' 10-1/2"	179.07
6		7' 10"	238.70
		7' 1"	215.90
7		6' 8"	203.20
		6' 6-1/2"	199.39
8		7' 9"	236.22
		7' 8"	233.60
9		6' 5"	195.58
		6' 3"	190.50
M		7' 0"	216.35
		6' 7"	208.26
SD		0.61	18.61
		0.65	20.70

R-L=Right to left stride

L-R=Left to right stride.

7 ft. 10 in. (238.70 cm) for both the curve and the straightaway. However, this was done by different individuals. The athletes with the best times on the curve increased their right to left strides in comparison to that on the straightaway. It was noted that the athlete with a superior time on the curve (11.24 sec.) increased her right to left stride by 5 cm over that obtained on the straightaway. All runners achieved a greater right to left stride on the curve. A possible explanation is because the runner is leaning to the inside as a result of centripetal force, the outside foot will apply force over a longer period of time, thus giving a longer right to left stride.

The average stride rate was 4.12 strides per second for the straightaway and 4.20 strides per second for the curve. The statistical analysis of a paired _t_ test indicated no significant difference between stride length on the straightaway and the curve. These results appear in Table 10.

Chapter V is a presentation of the summary of the investigation and the conclusion to the study. Included in this chapter are recommendations for furhter studies.

Table 10

Results of Paired t Test Between Stride Length on the Curve and Stride Length on the Straightaway

Variable	N	M (in)	SD (in)	SEM (sec)	t NS
Stride Length Straightaway	9	7.024	0.6907	0.2322	0.027
Stride Length Curve	9	7.104	0.6239	0.0280	

t .05 $\bar{<}$ 1.860.

t NS = not significant.

Chapter V

Summary, Conclusion, and Recommendations for Further Studies

Summary of the Investigation

The investigation entailed a study of the comparison of elapsed time on the straightaway and the curve for 100 m. The major purpose of this research project was to determine if there were any differences between elapsed time on the straightaway and the curve. The relationship between leg length and stride length, and height and stride length, and the differences between stride length on the straightaway and the curve was considered also. A review of the literature indicated that the factors investigated in this study were not duplicated. No comparative research involving female sprinters was discovered with respect to the factors relevant to linear and curve running.

In recent years several studies relating primarily to male subjects and sprinting have been completed. These studies have been concerned for the most part with factors which sought to determine just where a runner reaches peak velocity while running the 100 m on the straightaway.

Preliminary procedures included assimilating of information pertinent to the study, developing a tentative outline which was presented to the thesis committee and, in corrected form, filed as a prospectus in the office of the Provost of the Graduate School. Prior to the filing of the prospectus, permission was secured from the Human Subjects Review Committee to conduct the study. Written permission was also received form the subjects. The investigator selected nine female members of the Texas Woman's University track team as subjects.

Instruments used in the study consisted of an electric timer and photo-electric cells. Stride length was measured between the 40 and 70 m segments of the 100 m. This was done by measuring the imprint from touch-down of the left foot to touch-down of the right foot. Each subject was timed according to established criteria. The study was conducted in May 1981, at the Texas Woman's University, in Denton, Texas.

Findings of the Study

The following findings were obtained during the conduction of the study:

1. Results of a paired $\underline{t}$ test indicated significant differences between elapsed times on the straightaway and the curve for 100 m in favor of the straightaway.
2. Results of a 2 factor repeated trials ANOVA showed that the velocity for both the two conditions and the different segments were different. Because of

non significant interaction analysis of main effects indicated significant differences at the 20-40 m, 40-70 m, 70-90 m and 90-100 m segments of the 100 m between the straightaway and the curve.

3. A greater velocity occurred during acceleration in the first 20 m on the curve than on the straightaway.
4. Velocity increased through the 40-70 m segment on both the straightaway and the curve.
5. Deceleration occurred from the 70-90 m segments for both conditions, but a greater deceleration occurred on the curve.
6. An increase in mean velocity occurred from the 90-100 m mark that was faster on the straightaway than the curve runs.
7. A statistically significant correlation was found between height and stride length (r = .583). This was not considered of sufficient value to be useful.
8. On the curve all of the runners had a greater right to left stride length than left to right.
9. A statistically significant coefficient of correlation exists between stride length and leg length (r = .983).
10. Results of a paired _t_ test showed no significant difference between stride length on the straightaway and the curve.

Conclusion

Based upon the findings of this investigation it may be concluded that sprinters run faster on the straightaway than on the curve. The dynamics of good curve runners are not known, but the factors of stride length, stride rate, leg length, and height do not necessarily indicate superior results on the curve.

Recommendations for Further Research

The investigator submits the following recommendations for further studies:

1. Replicate the present study using male athletes.
2. Conduct a similar study using European athletes.
3. Replicate the present study using the starting blocks.
4. Conduct a similar study with the analyses of stride length and stride rate during the entire 100 m, to determine which of these factors have a greater effect on the time elapsed.
5. Study the support time of the right and left feet during various segments of curve running.

Appendix A

Time Intervals on the Straightaway

Subjects	Start To 20 M	20- 40 M	40- 70 M	70- 90 M	90- 100 M
1	2.49	2.11	3.25	2.22	1.12
2	2.75	2.07	3.41	2.10	1.00
3	2.76	2.10	3.28	2.15	1.02
4	2.81	2.42	3.71	2.87	1.28
5	2.78	2.49	3.62	2.51	1.00
6	2.70	2.44	3.45	2.46	1.00
7	2.85	2.68	3.46	2.51	1.20
8	2.78	2.57	3.50	2.18	1.30
9	2.78	2.20	3.42	2.73	1.06
Mean	2.74	2.34	3.45	2.41	1.14
SD	0.10	0.22	0.14	0.27	0.13

Appendix B

Timed Intervals on the Curve

Subjects	Start To 20 M	20- 40 M	40- 70 M	70- 90 M	90- 100 M
1	2.54	2.14	3.25	2.20	1.09
2	2.63	2.21	3.35	2.41	1.10
3	2.43	2.23	3.52	2.11	1.12
4	2.62	2.55	3.83	3.73	1.65
5	2.67	2.55	3.90	2.83	1.15
6	2.48	2.34	3.58	3.35	1.10
7	2.57	2.72	3.78	3.36	1.30
8	2.86	2.80	3.57	2.44	1.24
9	2.88	2.17	3.35	2.53	1.43
Mean	2.62	2.41	3.57	2.77	1.24
SD	0.14	0.24	0.22	0.57	0.30

Appendix C

Stride Length - Stride Rate During Maximum Velocity

Subjects		Straightaway Stride Length (cm)	Straightaway Stride Rate Strides/sec.	Curve Stride Length (cm)	Curve Stride Rate Strides/sec.
1	R-L	210.80	4.50	215.90	4.39
	L-R	205.70		201.90	
		416.50		417.80	
2	R-L	238.70	3.78	234.95	3.82
	L-L	226.06		234.95	
		464.76		469.90	
3	R-L	236.22	3.94	228.60	3.76
	L-R	226.06		223.52	
		462.28		452.12	
4	R-L	185.42	4.21	193.04	4.08
	L-R	198.12		190.50	
		383.54		383.54	
5	R-L	187.96	4.47	200.66	5.94
	L-R	182.88		179.07	
		370.84		379.73	
6	R-L	223.52	3.94	238.70	3.68
	L-R	218.44		215.90	
		441.96		454.60	
7	R-L	198.12	4.33	203.20	3.94
	L-R	201.93		199.39	
		400.05		402.59	
8	R-L	238.70	3.63	236.22	3.58
	L-R	233.60		233.60	
		472.30		469.52	
9	L-R	198.12	4.35	195.58	4.63
	L-R	205.74		190.50	
		403.86		386.08	

Appendix D

Correlation Matrix

	1 H	2 W	3 LL	4 SLST	5 SLC	6 TST	7 TC
1 Height	1.00 *						
2 Weight	.741 *	1.00 *					
3 Leg Length	.680 *	.701 *	1.00 *				
4 Stride Length ST	.583 *	.089	.983 *	1.00 *			
5 Stride Length C	.582 *	-.301	.981 *	.810 *	1.00 *		
6 Time ST	-.017	-.350	-.522	-.654 *	-.012	1.00 *	
7 Time C	-.138	-.354	-.522	-.590 *	-.641*	.971 *	1.00 *

Stride Length ST = Stride Length on the Straightaway

Stride Length C = Stride Length on the Curve

H = Height

W = Weight

LL = Leg Length

SLST = Stride Length on the Straightaway

SLC = Stride Length on the Curve

TST = Time on the Straightaway

TC = Time on the Curve; * $p < .05$

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