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The purpose of this study was to analyze and compare mechanical differences in the execution of the fastest and slowest of twelve crouch starts at a five yard distance as they were executed by a woman sprinter. After viewing the filmed starts, the fastest and slowest starts were determined by counting the number of frames required for each start. Angle measurements of the elbows, knees, legs at the hip, head at the trunk, and the trunk with the horizontal were obtained and the average angular velocities were computed for every third frame at each of the angles. The two starts were analyzed to determine similarities and differences in execution.

The two starts were compared to determine similarities and differences which may have contributed to the one start being faster than the other. The analysis revealed a high head position in the slowest start as compared with the fastest sequence in which the head was kept low and in line with the trunk. The runner maintained a lower body position after the first stride in the fastest start and moved into this position sooner. The body position in the slowest sequence was more upright throughout the run and paralleled the high head position.

The length of the first stride out of the blocks was longer in the fastest start and was executed with a greater velocity. The velocity and distance of the second stride out of the blocks was also greater in the fastest start. The average velocity of the left

arm was greater in the fastest start and appears to have been driving much harder. The average right arm velocities were the same for both starts.

A CINEMATOGRAPHIC ANALYSIS OF THE CROUCH START AS PERFORMED BY A WOMAN SPRINTER

by

Karen Ruth Dix

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APPROVAL PAGE

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CHAPTER I

INTRODUCTION

The history of women's participation in track and field events can be traced back to the time of the Greeks. At this time, women were barred from participation in the early Greek games, the Olympiad. Under the influence of Hippodameia, the Heraea Games were organized to provide competition for women. These games were held secretly every four years, but were abolished in 394 AD when the Olympic Games were also abrogated. (10:8) When the Olympic Games were resumed, women still were not allowed to participate openly in track and field events until the Amsterdam games were held in 1928.

Participation in the Olympics has contributed greatly to the steady and rapid growth of track and field for women. This growth has been further promoted and developed with the inclusion of track and field in high school and college curriculums. Many skill and ability levels can be accommodated through a track and field program. Within the sports structure of schools, recreation departments, and athletic federations, there is ample opportunity for all to participate.

Numerous articles and books have been written relative to techniques and training of women track and field athletes; however, very little research has been done using women as subjects. This is particularly true in relation to the crouch start for

women; the topic is discussed and described but not supported. Crouch starting for men has been thoroughly studied and researched; the majority of women's track and field books suggest adaptations of the techniques employed by men. Since there are physiological differences between sexes, it is incongruous to assume women's techniques should be developed on the basis of the performance of men. The need for research in this area is great.

Various research techniques are used to study movement patterns; one of the more accurate means is through the use of cinematography. The value of this type of study was clearly stated by T. K. Cureton:

> Fairly precise analysis of the external mechanics of many acts of skill may be made by cinematography. The fundamental principle is that directions of movements (angles), dimensions, time relations, and indirect values of force and velocity may all be obtained from the projected film. (11:5)

The idea for this study was prompted by the author's interest in track and field and by a realization of the importance of research in the validation of theories. Women's track and field has been undergoing a tremendous growth spurt during the last two decades. Women physical educators have an obligation to teach the most efficient and proper techniques and to adequately answer the needs and demands of interested girls.

Statement of the Problem

The purpose of this study was to analyze and compare mechanical differences in the execution of the fastest and slowest of twelve crouch starts at a five yard distance as they were executed by a woman sprinter.

The analysis of the starts was concerned with the sequential order of movement and with the various velocities and angles of body parts during the start and the first five yards.

Limitations of the Study

This study was limited to the use of one experienced woman sprinter using one foot position and one hip position. Filming was done from one angle only, using one camera.

Definitions

1. Crouch Start - a body position which permits the greatest amount of force to be exerted to overcome inertia.
2. Medium Position - the knee of the rear leg is placed approximately opposite the instep of the front foot, and the hips are elevated to a position slightly higher than the shoulders.

CHAPTER II

REVIEW OF LITERATURE

The literature reviewed for this study included textbooks in track and field, studies relative to the crouch start for both men and women, and studies dealing with cinematographic analysis.

Principles of Crouch Starting

The purpose of the crouch start is to put the runner in a position which will allow her to get away from the starting blocks and into the running stride as quickly as possible. Prior to the start, the runner's equilibrium (center of gravity) should be in the least stable position and the feet should be in a position "that permits the greatest amount of force to be exerted over the longest distance in the desired direction, in order to overcome inertia." (1:105)

Newton's Law of Acceleration states that the force is equal to the mass of the body times the acceleration. Therefore, the push exerted by the feet times the time this force acts against the blocks equals the momentum of the body as it leaves the blocks.

The vigorous arm action evidenced in the drive from the blocks and the first few strides of the start illustrate Newton's Law of Reaction. The arms move in opposition to the legs and they help balance the body and are thought to aid in acceleration of the body.

The angle at which the body leaves the blocks is also important. If the angle at which the body drives out of the blocks is too large, the body will move more in a vertical direction than in a horizontal direction. If the angle is too small, the reverse will be true. Therefore, the body should come out of the blocks at an angle which will allow the runner to stay low and yet obtain the maximum amount of force possible from the feet.

Track and Field Books

Numerous women's track and field books were reviewed to determine the recommended techniques for the execution of the crouch start. Descriptions of these books are divided into (1) recommended stance, (2) "on your marks" position, (3) "get set" position, and (4) start.

Scott and Crafts recommended the medium position because it "has been found experimentally to provide the most effective starting position." (8:33) In the "on your marks" position, the arms should be straight and aligned directly under the shoulders. The head should be down with the eyes looking in front of the starting line. In the "get set" position, the runners weight is shifted forward and slightly upward by bringing the knee of the rear leg about four inches off the ground. The hips are raised so the back and neck form a line parallel with the ground. The eyes look at a spot about eight yards down the track, or they may be directly in front of the runner. In the "start" position, the first step is with the rear foot and the opposite arm reaches out

and straight ahead. The arms continue to move in opposition to the legs. The first step is fairly long and the foot should barely clear the ground. The knee of the forward leg should remain well bent as the first stride begins, allowing an immediate complete extension of the rear leg. The length of the stride depends on the length of the performer's legs and the speed at which they are moving. The body remains in a forward lean until about seven to ten yards from the starting line. (8:32-39)

Pugh and Watts advised a medium position also. In the "on your marks" position, the hands are shoulder width apart and straight and the eyes are focused about a yard in front of the hands. In the "get set" position, the shoulders are in advance of the starting line and the hips are slightly higher than the shoulders. The head is in line with the back and the eyes remain focused about a yard in front of the hands. The angle of the front knee is approximately 90 degrees and the rear leg between 110 and 120 degrees. In the "start" position, the head remains aligned with the body and leads. The trunk remains parallel with the ground as the front foot continues the drive. A high knee lift should occur with the first stride and continue throughout the race. The arms should remain bent at the elbows and the hands should be loosely cupped. (7:11-21)

Miller suggested the medium starting position. In the "on your marks" position, the hands are placed slightly more than shoulder width apart. The eyes are focused about two feet in front of the starting line. In the "get set" position, the hips

are raised slightly higher than the shoulders. In the "start" position, the drive of the legs is accompanied by forceful arm swings. The arms should move obliquely across the body from the shoulder height to a point six inches behind the outside of the hips. The body remains low and the first few strides are relatively short and should be a natural reaction. (5:32-35)

Thompson recommended the medium start because the position permits a powerful contribution of both legs to the initial drive and heightens the effectiveness of the final thrust of the front leg in building up acceleration. In the "on your marks" position, the hands are placed shoulder width apart and the arms are straightened to keep the shoulders high. The eyes are focused three to five inches in front of the line. The head remains aligned with the body. In the "start" position, the arm movements are in opposition to the legs and are just powerful enough to balance the leg actions. The body remains low for ten or fifteen yards. (9:8-12)

Foreman and Husted discussed the medium position because it combines the best elements of the bunch and elongated starts. In the "on your marks" position, the hands are placed shoulder width apart and the head hangs in a natural position. In the "get set" position, the arms are straight and the shoulders move three to four inches ahead of the starting line. The front leg is at about an 80 degree angle and the rear leg about 130 degrees. The hips are slightly above the shoulders and the back is with the head in line with the body. In the "start" position, the action

sequence (for a sprinter with the right foot back) is right arm, left arm, right foot, left foot. The first foot out of the blocks contacts the track about twenty-four inches ahead of the starting line. Each stride will increase in length until maximum acceleration is attained. (3:34-38)

Wakefield, Harkins, and Cooper did not specify or describe one start in particular; although they did recommend either a bunch or medium position. In the "on your marks" position, the hands are placed about shoulder width apart. The arms are straight and the head is hanging down to avoid tenseness. In the "get set" position, the hips are raised slightly higher than shoulder level and the shoulders move ahead of the hands. The head is held down with the eyes looking directly down at the track. In the "start" position, the rear leg leaves the block first and takes a reasonably long step but the foot remains close to the ground. The arms work in opposition with a thrusting action. The body weight should be kept in front of the feet. (10:35-39)

Jackson suggested using either the bunch or medium position but she advocated the medium because it puts the runner into the running stride the fastest. In the "on your marks" position, the arms are relatively straight but not hyperextended, and the hands are shoulder width apart. The shoulders are over the hands and the head is in line with the trunk. The eyes are focused approximately three feet in front of the starting line. In the "get set" position, the hips are even with or slightly higher than the shoulders and the shoulders move two or three inches ahead of the

hands. The eyes remain focused approximately three feet in front of the starting line. In the "start" position, the arms and the legs work in opposition and the arms should maintain angles close to 90 degrees. The shoulders remain parallel to the ground as the feet push off the blocks. The first step is as long as possible and each step should become increasingly longer. (4:27-37)

Parker and Kennedy advised using the medium start until the runner becomes trained and can make her own adjustments. In the "on your marks" position, the hands are placed shoulder width apart and the weight is slightly forward with the shoulders a few inches ahead of the starting line. In the "set" position, the hips are raised slightly higher than the head and the front leg should form an angle of about 90 degrees at the knee and the rear leg in excess of a 90 degree angle. The eyes are focused about three feet in front of the starting line. In the "start" position, the hand opposite the rear foot swings up and forward in a short uppercut motion. The arm movement should be done with the greatest possible speed and coordination. The first step should be at least twelve inches beyond the line. The knees should be lifted higher on each successive stride. (6:17-24)

Studies Relative to the Crouch Start

Studies relative to the crouch start for men have been numerous, dating back to the early 1930's when the work of Kistler (16), Dickinson (14), and Cureton (12) made outstanding contributions to the analysis of the "proper" method. The method

of crouch starting was invented in 1877 by Mike Murphy of the University of Pennsylvania. It was first used by Charles H. Sherrill at the Rockway Hunt Club games at Cedarhurst, Long Island on May 12, 1888. (12:14)

Types of starts and spacings of blocks were researched by Dickinson (14), Henry (15), and Stock (17). Henry and Dickinson found the bunch starting position allowed the runner to clear the blocks sooner but Henry found the bunch start resulted in the least amount of velocity at ten and fifty yards. Stock timed twenty-six track men and found the medium and the medium-high hip position to be significantly faster at twenty and fifty yards.

A review of previous studies done in the area of the crouch start for women revealed a limited amount of information. A study by Hulstrand dealt with the lateral foot placement in the crouch start. (18) She used thirty-seven college women in her study; thirteen experienced and twenty-four inexperienced. Each subject performed six starts using three different lateral foot placement positions (narrow, medium, and wide). Each start was timed at a five yard distance by a timing device which was started by the release of the back foot and was stopped by breaking a string at the finish line. She found the mean starting time for the five-yard distance for the medium position of the inexperienced runners to be 1.311 seconds and the mean time for the experienced runners to be 1.183. She did not find any significant difference in the three foot placements but suggested further research be done in the area of the crouch start for women.

Cinematographic Studies and Techniques

The filming of rapid movement had its beginning with the experiments of Muybridge in the late 1870's. (11:4) Development of techniques and the discovery of new uses for cinematographic analysis have occurred since this time, and numerous studies utilizing these techniques are found in research.

A review of previous studies done in the area of track and field using cinematography revealed that none have been done for women in relation to the crouch start. A cinematographic analysis of the crouch start was included in a study of men done by Lanier. (19) He studied eighteen starts done by an experienced fifty yard man sprinter on film and then compared the results with the results he obtained from the same eighteen starts as they were recorded with force-blocks designed to measure horizontal velocity.

Lanier set his camera on a tripod three feet above the floor and twenty-four feet from the line of sprinting and perpendicular to a line one foot in front of the starting line. Following a fifteen minute warm-up period, the subject was given three practice starts. All eighteen recorded starts were timed at a distance of twenty yards but were filmed only until the sprinters back foot touched the ground. Utilizing the measurement of the center of gravity, he determined the average velocity to be nine feet per second for the first .45 seconds of movement. He suggested further study be done in the area, finding the relative error in determining velocity by the cinematographic analysis techniques to be twice as large as by the force-block method.

A cinematographic analysis of sprint running was done by Deshon and Nelson. (13) Ten track sprinters and nine baseball players were filmed over a distance of fifteen yards. The camera was placed 155 feet back and perpendicular to the center of the fifteen yard filming zone. The speed of the camera was calculated by using the ball drop technique and yardsticks were photographed in the plane of action to correct for linear measurement. The analysis was done on selected crucial frames throughout the one hundred frame film strip.

Summary

In view of the literature reviewed, the following conclusions seem plausible:

1. A limited number of studies have been done relative to the crouch start for women.
2. Very few studies of men or women have been done involving cinematographical analysis of the crouch start.
3. The literature available on the crouch start for women indicates very little scientific evidence on which to base coaching techniques for crouch starting for women.

CHAPTER III

PROCEDURE

The purpose of this study was to analyze and compare the mechanical differences in the execution of the fastest and slowest of twelve crouch starts at a five yard distance as they were executed by a woman sprinter.

Selection of Subject

One experienced woman sprinter from the Graduate School at the University of North Carolina at Greensboro was the subject used in this study. The sprinter had previously competed as a member of a high school track team and as a member of a college track team.

Equipment

The filming was done with a Bolex H16 sixteen mm spring driven motion picture camera equipped with a 25 mm lens. The film used was + type 7276.

Placement

The filming was done on an asphalt track. To allow a clear and constant background, a twenty-one foot backdrop was placed parallel to the lane and twenty-three inches from the starting block. This backdrop was five feet high and extended five feet behind the starting line to include the runner prior

to the start. The starting line and a line five yards down the track were marked on the backdrop with a vertical strip of white tape.

The camera was mounted on a tripod five feet above the ground and was placed sixty feet six inches from the center and perpendicular to the twenty-one foot filming area.

Figure 1, page 15, shows a diagram of the filming situation.

Reference Points and Measurements

For the purpose of this study, the subject was dressed in a two-piece swimming suit and tennis shoes. She was marked with a black water color felt tip pen. The head was marked by placing a white swimming cap on her head and then placing the marks on the swimming cap. Reference points were marked in the following places:

1. A point between the distal end of the radius and ulna on the posterior side on the left arm and on the anterior side on the right arm (when the body is in the anatomical position).

2. The lateral epicondyle of the distal end of the humerus on the left arm and the medial epicondyle on the right arm.

3. The posterior edge of the glenohumeral joint center.

4. The lateral bony prominence of the greater trochanter on the left side of the body.

5. The lateral epicondyle of the distal end of the femur on the left leg and the medial epicondyle on the right leg.

6. The lateral malleolus of the left ankle and the medial malleolus of the right ankle.

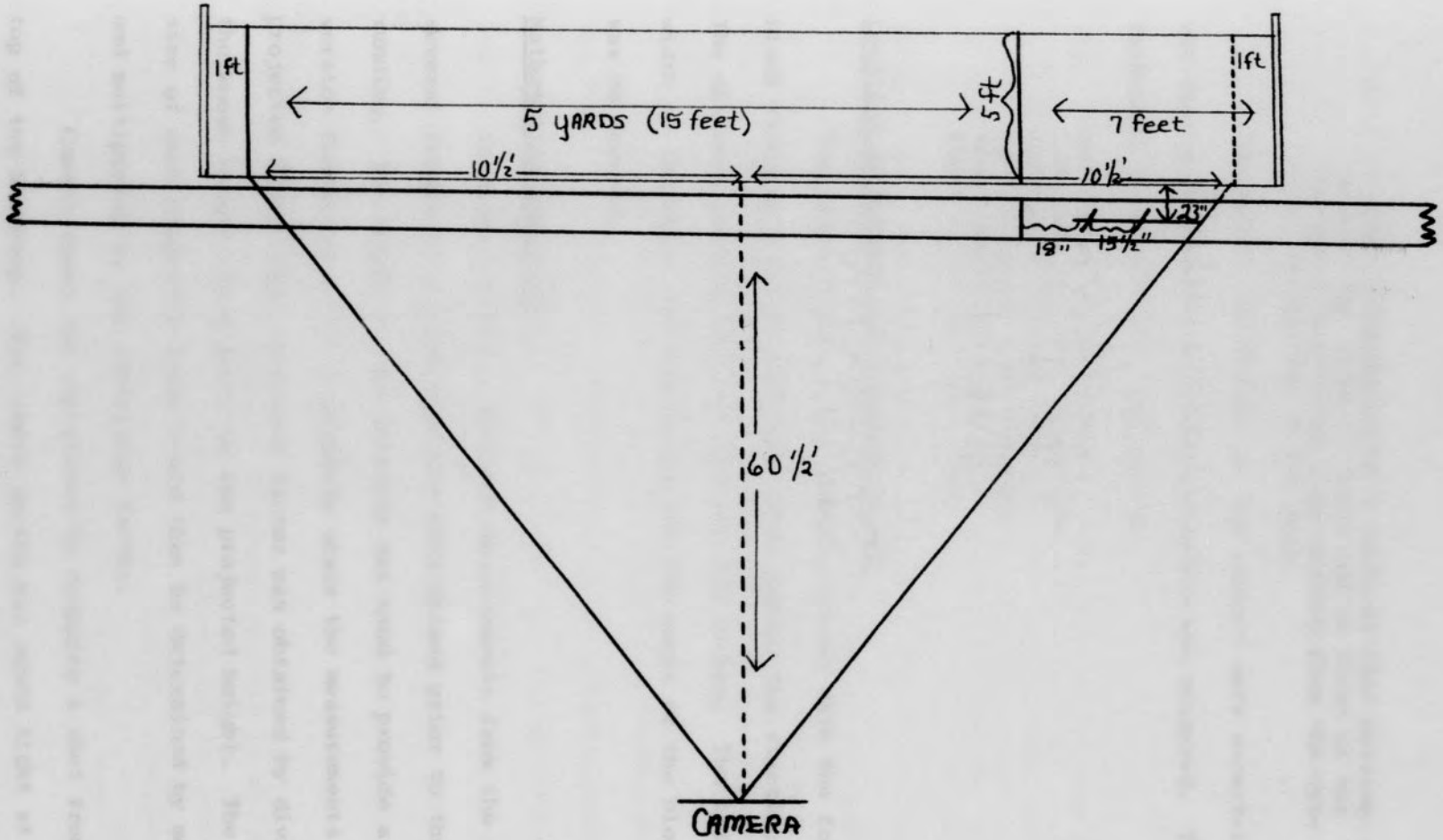

FIGURE 1

DIAGRAM OF THE FILMING SITUATION

7. A point intersected by a vertical line passing through the temporal fossa and in front of the ear and a horizontal line running from the eyebrows to the top of the ears.

The height and weight of the subject were ascertained and the distance between the reference points was measured. The following distances were determined:

Left ankle to left knee
Left knee to left trochanter
Left wrist to left elbow
Left elbow to left shoulder
Right ankle to right knee
Right wrist to right elbow.

Location of Subject and Starting Blocks

The subject placed her starting blocks with the front block fixed at a point eighteen inches behind the starting line. The distance between her two feet was 15½ inches. The lateral width of the block was 10½ inches and the angle of the blocks was 68 degrees.

Mathematical Constants

In order to obtain distance measurements from the film, several frames of a known distance were filmed prior to the actual running. The height of the backdrop was used to provide a conversion factor in order to properly scale the measurements on the projected film. The conversion factor was obtained by dividing the known height (five feet) by the projected height. The actual size of each projected image could then be determined by measuring and multiplying by the conversion factor.

Camera speed was calculated by dropping a shot from the top of the backdrop. The camera spring was wound tight at the

beginning of the two drops. The average number of frames for the two drops was used to calculate the speed of the camera. The formula $S = \frac{1}{2} gt^2$ was used.

S = distance the object fell
g = 32 feet/second^2
(acceleration due to gravity)
t = time in seconds

The actual speed of the camera was determined by solving for t in the formula and then dividing by the average number of frames it took for the object to fall the five foot distance.

Filming

The filming was done from the left side of the sprinter to allow the best shot of the front leg which maintained contact with the block the longest time. The sprinter was allowed to warm up using her own discretion.

The sprinter was called to her mark by a starter and as she assumed her position, the filming began. She was started with a gun only to make the situation realistic. The sprinter ran past the end of the backdrop. Only the start and the first five yards of the sprint were filmed. She was allowed to rest between each start and the same procedure was followed for twelve starts.

Collection of Data

The film was viewed on a Magnasync Moviola 16 mm Table Viewer. A total of twelve starts was viewed and the number of frames for each five yard sequence was counted. From these twelve starts the sequence consisting of the least number of

frames was selected as the fastest. The slowest start was determined by selecting the sequence consisting of the most number of frames. The counting of frames began with the frame prior to the first movement shown by the right hand and ended with the frame showing the greater trochanter mark passing the tape marking at the end of the five yard distance. Six sequences were determined to involve eighty-seven frames; on the basis of clarity and clear observation of reference points, one of these six was selected to represent the slowest run. Page 64 in the Appendix illustrates these twelve runs and the number of frames involved in each. The runs are listed in the order in which they were performed.

The first frame and every third frame thereafter were selected for analysis. There were a total of eighty-seven frames involved in the slowest start and eighty-four frames involved in the fastest. Because these numbers were not evenly divisible by three, the last measurement frame was two frames from the previous measurement frame.

The frames involved in the analysis were then traced by placing a transparency over the viewer screen and marking the reference points with a felt tip pen. These reference points were permanently recorded on tracing paper and lines were drawn to connect these reference points. The angles formed at the elbows, knees, legs at the trochanter marking, the angle formed by the head and the trunk, and the angle of the trunk with the horizontal

were measured with a protractor. To be consistent in the measurement of the angles, measurements showing a decrease in the number of degrees over the three frame movement sequence were called flexion and those movements showing an increase were referred to as extensions. The trunk angle was determined by extending the trunk line which passed through the greater trochanter mark and shoulder mark. The angle formed at the point at which this line intersected a horizontal line drawn parallel to the track was then measured.

The length of the stride was determined by measuring the actual distances on the screen with a ruler and then converting the linear measurements. Sequential order of movement was also recorded based on a frame by frame observation.

CHAPTER IV

ANALYSIS OF DATA

Figure 2, page 21, and Figure 3, page 24, Table I, page 22, and Table II, page 25, present the tracings and angles as they were measured from the traced image. The missing angles for the right arm measurements represent the frames when the right arm was blocked from view either by the left arm or by the body. The marking on the left shoulder was not always clearly visable because of rotation. Therefore, the point for measurement was marked on the extreme anterior border of the shoulder.

The actual speed of the camera was calculated by using the formula

$$S = \tfrac{1}{2} gt^2 \text{ and the ratio } \frac{\text{number of frames it took the shot to fall}}{t} \times \frac{x}{1 \text{ second}}$$

By solving for x in the formula, the speed of the camera was determined to be 61.6 frames per second. The time per frame was determined by the ratio

$$\frac{t}{\text{number of frames it took the shot to fall}}$$

The time per frame was determined to be .016 seconds.

The vertical reference point filmed at the beginning of the filming measured five feet. The same distance measured on the projected film was one inch. Therefore, the conversion factor

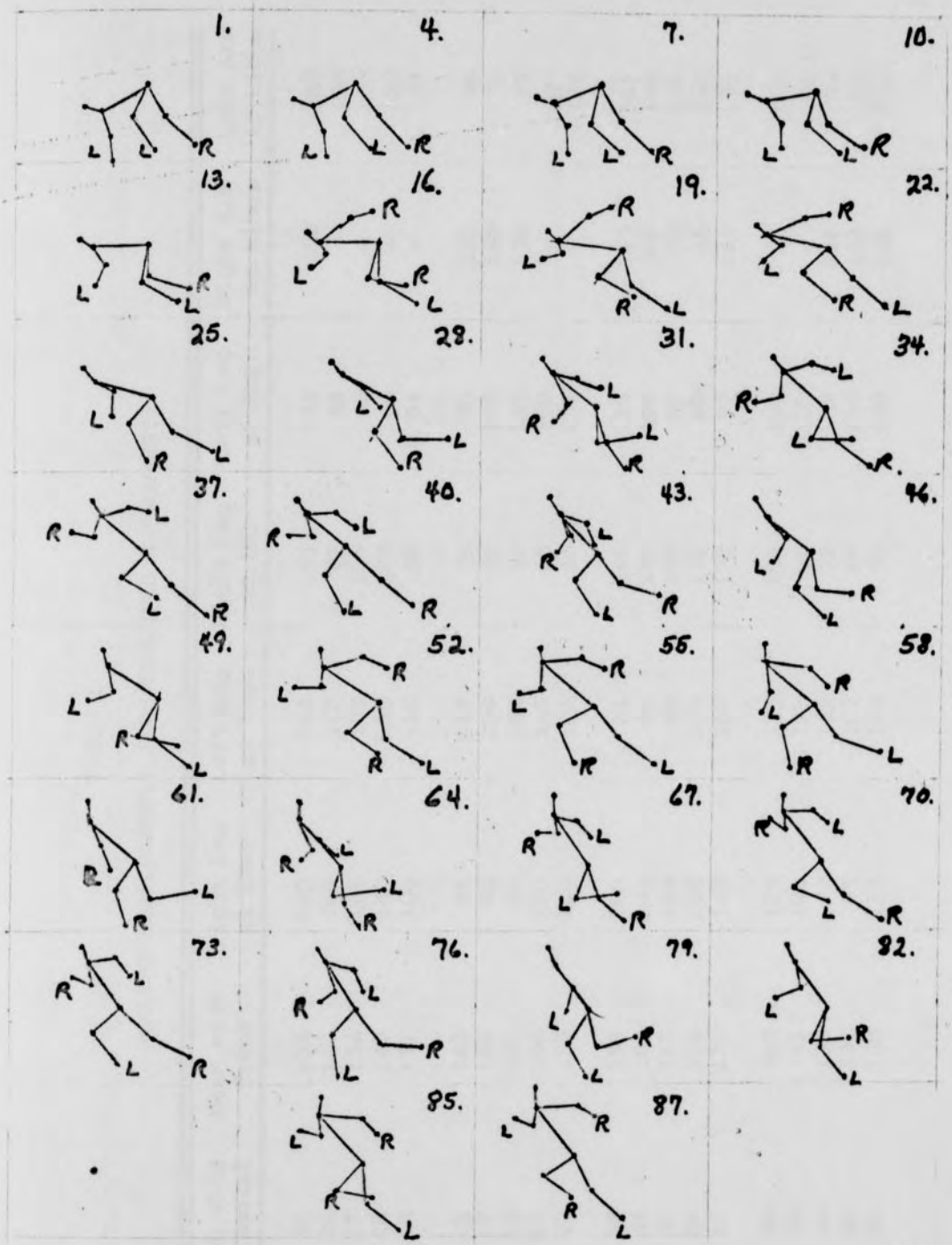

FIGURE 2

SEQUENCE A (SLOWEST)

TABLE I

ANGULAR MEASUREMENTS FROM SEQUENCE A (SLOWEST)

Frame	Trunk with Horizontal	Head with Trunk	Right Leg at Knee	Left Leg at Knee	Right Leg at Hip	Left Leg at Hip	Right Arm at Elbow	Left Arm at Elbow
1	30	133	160	122	91	35	162	162
4	29	124	169	117	97	42	-	166
7	17	152	165	122	107	63	-	153
10	12	143	145	116	102	64	-	150
13	3	151	106	112	90	81	-	124
16	1	142	88	117	76	90	157	90
19	7	154	81	134	58	109	160	73
22	12	150	86	164	52	138	159	79
25	17	146	110	146	65	138	-	120
28	22	155	120	106	90	131	-	156
31	37	158	160	81	149	129	119	167
34	41	169	142	66	150	106	109	140
37	39	167	168	88	167	87	93	144
40	38	156	168	110	171	89	68	138
43	47	170	145	107	170	97	114	133
46	39	162	103	115	136	109	-	110
49	33	141	100	128	96	120	-	91
52	33	129	73	133	72	133	141	90
55	42	137	95	162	69	169	143	105
58	41	140	113	143	75	166	141	157

TABLE I (continued)

Frame	Trunk with Horizontal	Head with Trunk	Right Leg at Knee	Left Leg at Knee	Right Leg at Hip	Left Leg at Hip	Right Arm at Elbow	Left Arm at Elbow
61	41	143	124	100	95	150	-	176
64	49	137	147	70	149	129	112	168
67	55	151	150	65	161	124	75	144
70	53	141	160	67	178	94	40	140
73	58	165	169	96	198	99	57	124
76	55	169	127	127	180	102	99	131
79	57	175	89	128	161	120	-	130
82	53	166	61	133	118	139	-	94
85	48	132	55	130	91	143	141	66
87	51	146	72	155	83	164	145	73

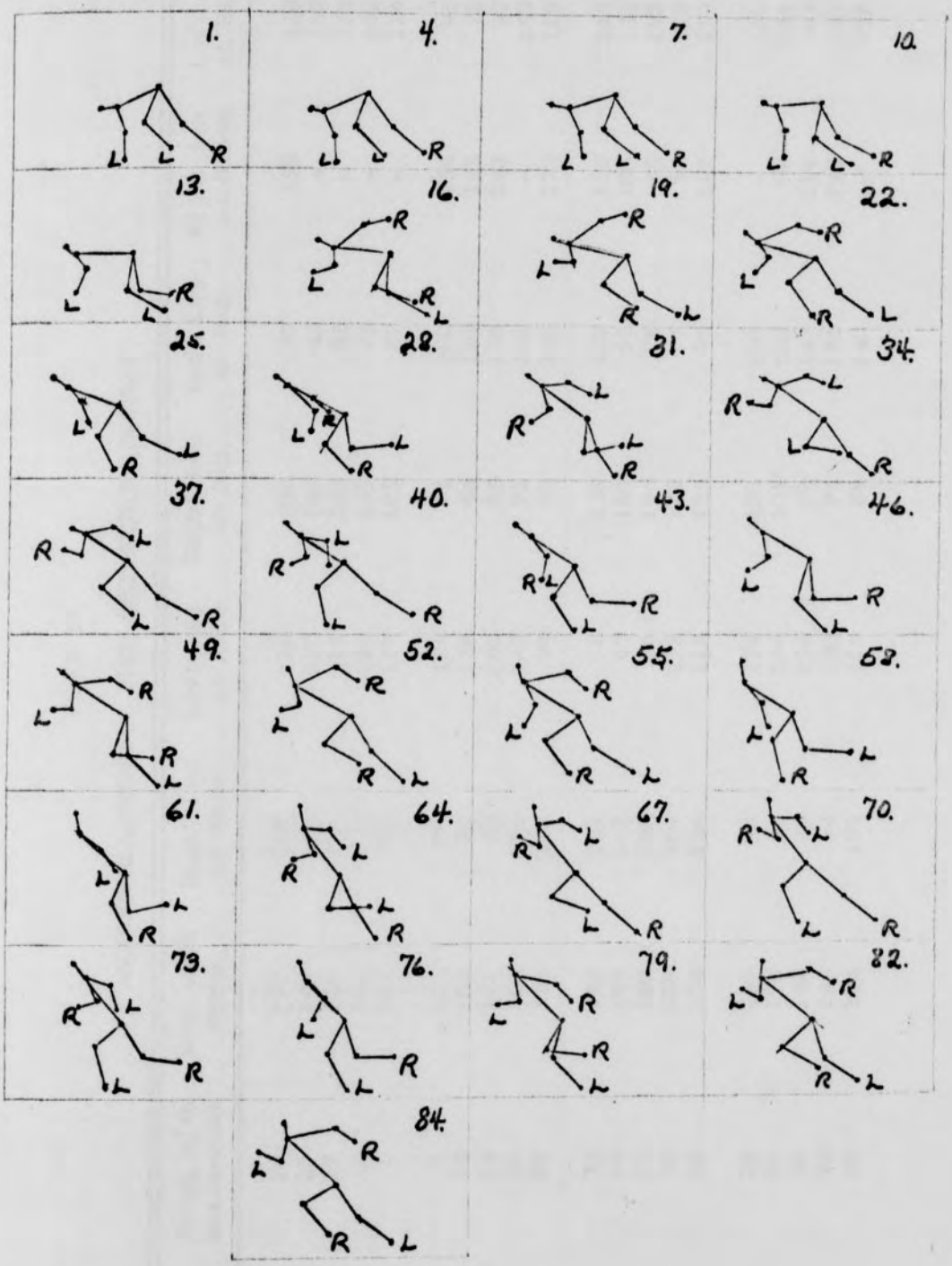

FIGURE 3

SEQUENCE B (FASTEST)

TABLE II

ANGULAR MEASUREMENTS FROM SEQUENCE B (FASTEST)

Frame	Trunk with Horizontal	Head with Trunk	Right Leg at Knee	Left Leg at Knee	Right Leg at Hip	Left Leg at Hip	Right Arm at Elbow	Left Arm at Elbow
1	24	159	168	110	109	39	158	158
4	23	141	165	113	102	45	-	162
7	17	156	158	111	105	55	-	158
10	5	159	134	110	105	71	-	150
13	1	157	111	117	102	87	-	124
16	6	157	86	121	71	100	154	95
19	13	182	81	139	64	123	155	72
22	13	151	95	160	55	138	142	93
25	20	163	115	143	71	142	-	153
28	29	170	112	94	89	130	172	119
31	33	181	151	76	138	122	112	143
34	34	188	167	67	160	91	105	134
37	35	160	161	86	164	78	85	122
40	34	178	169	112	170	77	97	118
43	34	174	124	118	155	93	152	152
46	29	160	94	122	123	100	-	111
49	32	170	77	134	101	122	99	134
52	32	148	76	154	75	147	119	93
55	34	145	94	150	73	151	123	130
58	33	134	129	113	88	140	-	157

TABLE II (continued)

Frame	Trunk with Horizontal	Head with Trunk	Right Leg at Knee	Left Leg at Knee	Right Leg at Hip	Left Leg at Hip	Right Arm at Elbow	Left Arm at Elbow
61	43	148	125	81	138	110	-	160
64	54	151	160	67	163	127	76	140
67	51	146	175	72	187	99	49	125
70	52	153	173	109	189	101	49	125
73	52	175	133	117	176	92	72	122
76	48	165	104	127	150	113	-	112
79	45	153	113	128	110	123	146	86
82	41	134	71	139	81	143	141	70
84	44	135	82	164	72	163	135	71

of sixty inches was used in all linear measurements. These measurements were made to the nearest thirty-secondth of an inch.

The velocity of the fastest and slowest sequences were calculated by counting the number of frames that elapsed from the frame prior to the first movement of the right hand and the time the greater trochanter mark passed the vertical five yard line on the backdrop. The following procedure was used to determine the velocity:

$$\frac{\text{actual speed of the camera per second}}{1} = \frac{\text{counted number of frames}}{\text{time}}$$

(solve for time)

$$\text{Velocity} = \frac{\text{Distance}}{\text{Time}} \qquad \text{(solve for velocity)}$$

The time for the slowest sequence was computed to be 1.392 seconds; the time for the fastest sequence was determined to be 1.344 seconds. The average velocity of the slowest run was determined to be 10.775 feet per second and the average velocity of the fastest run was 11.16 feet per second. The velocity of the body was also computed at a selected point in the five yard run. In Sequence A, the body velocity at the point the greater trochanter mark passed the vertical line at the end of the run was determined to be 19.5 feet per second. The body velocity in Sequence B at the point the greater trochanter mark passed the vertical line at the end of the run was also determined to be 19.5 feet per second. These velocities were determined by measuring the distance the greater trochanter mark moved in the last two frames and dividing by the time required to complete this movement.

The following procedure was used to determine the angular velocity for each of the body part angles measured in every third frame:

Degrees (Number of degrees the angle changed over the three frames)	=	Velocity	x	Time (Number of seconds the three frame sequence took)

Table III, page 60, and Table IV, page 62, in the Appendix present these angular velocities as they were determined by the above calculation.

Description of Sequence A (Slowest)

Figure 2, page 21, illustrates the tracings from Sequence A and Table I, page 22, presents the angular measurements taken from these tracings. Reference to these figure and table illustrations will be made throughout the description.

The sprinter assumed a medium crouch starting position with the left foot placed against the front block and the right leg extended with the right foot against the back block. The hips were raised slightly above the shoulders and the shoulders were slightly in advance of the starting line. The distance of the hips from the track was measured by drawing a vertical line through the greater trochanter mark and extending it down to the track. This distance measured 33.6 inches on Frame 1.

The angle of the right leg with the hip was 91 degrees and the angle at the knee was 160 degrees in Frame 1. The angle of the left leg with the hip was 35 degrees and at the knee was

122 degrees. The trunk was at a 30 degree angle with the horizontal and the head was at an angle of 133 degrees with the trunk. The angles of the right and left arm as measured at the elbow were 162 degrees and were considered to be the same because the arms were parallel at the start.

From the head position in Frame 1, the runner's eyes appeared to be focused on a point approximately three feet down the track and the weight of the body appeared to be shifted forward over the hands. The elbows were not locked prior to or during the start; the arms remained bent at the elbows at the start and throughout the sprint. The sequential order of the start was determined to be right arm, left arm, right foot, and left foot. This order was in complete agreement with the action sequence described by Foreman and Husted. (3:38)

The start began with the initial movement of the right hand as the runner raised her arm and moved it up and back toward her body. The right arm was obstructed from view by the left arm and the trunk for the first .192 seconds of the start or through Frame 13 and no measurements were taken until the right arm had passed the body and was on its way up and back.

Flexion of the left arm at the elbow began .096 seconds into the start as the arm was raised from the track. The left arm continued to drive forward for .192 seconds through Frame 19 at which time it began to drive back toward the body. The average time required for the left arm to complete its forward and backward drives throughout the sequence was .252 seconds.

The movement of the arms was in direct opposition to the movement of the legs as has been stated by authorities. The right foot left the back block .112 seconds into the start, or in Frame 7, and began to drive forward. This action paralleled the forward action of the left arm. The right leg completed its first step in the 28th frame, attaining an average velocity of 11.9 feet per second for the stride. At this time the left arm had already started to extend at the elbow to continue the momentum of the body parts.

The point at which the left foot left the block was between a three frame sequence; therefore, the film was further analyzed to determine the exact frame in which the foot left the block. The time the foot remained in contact with the block was considered to be related to the velocity of the leg as it came out of the block, thus a specific frame reading was required. The frame in which the front foot left the block was determined to be Frame 24, at which time the left foot had been pushing against the block for .384 seconds. The angles at the knee and hip of the left leg were decreased rapidly at the time of the push-off.

As the left leg was driving forward, the right arm was moving forward also. The average time required for the right arm to complete its forward and backward movement throughout the sequence was .276 seconds.

The angle of the head with the trunk was held relatively constant throughout the start and five yard run, rarely fluctuating more than 15 degrees within a three-frame period (.048 seconds).

There were four instances, however, when the head was raised or lowered more than 20 degrees within the three frames. One such instance occurred toward the end of the five yard run when the runner was attaining her balanced running posture and the head was raised 34 degrees over the three-frameperiod (.048 seconds). The steadiness of the head is in agreement with the techniques suggested by experts.

The runner covered the five yard distance in four full strides; the final stride by the right leg not being completed as the runner crossed the five yard line. The distance of each of these strides and the average velocities for each were computed.

Due to perspective error, a different conversion factor was used to determine the length of the stride of the first step from the back block. The known distance from the back block to the starting line was 33.5 inches; the distance measured on the film was 35.4 inches. The perspective error was determined to be 1.9 inches. This correction was only applied to the first stride by the right foot as it came out of the block. The perspective error in the rest of the run was considered to be too small to be of significance.

The distance of the first stride by the right leg was determined to be 48.5 inches and the average velocity was 11.9 feet per second. The second stride was executed by the left foot and covered a distance of 33.6 inches at an average velocity of 9.2 feet per second. The third stride by the right leg was 46.8 inches and was performed at an average velocity of 11.6 feet per second. The left leg executed the fourth stride which covered

58.2 inches at an average velocity of 12.6 feet per second. The increase in the distance of the stride as the run progressed was in agreement with the opinions expressed by Foreman and Husted (3:34-38) and Jackson (4:27-37). The decrease in average velocity to 9.2 feet per second in the second stride indicates the left leg did not drive out of the block with a great deal of force or speed. The movement of the left leg for this stride required .304 seconds. There was an increase in the length of stride after the right foot left the block, and there was also an increase in the velocity of the stride as would be expected.

When the arms were in the backswing and at their highest point, they consistently began their downward movement prior to the frame in which the same foot touched the track. This point is illustrated in Frames 40, 58, and 76 where the arm had already begun its forward motion as the lead foot touched the track. The left arm required .192 seconds to move forward as opposed to the .336 seconds required by the right leg in the first stride. The right arm moved forward with the left leg and required .288 seconds; the left leg stride required .304 seconds. The left arm again drove forward with the right leg utilizing .240 seconds compared to the .336 seconds utilized by the right leg. In the last stride analyzed, the right arm required .288 seconds and the left leg required .384 seconds.

The right arm was consistently obscured from view by the body as it passed the body on its forward and backward motions and as a result no measurements or angular velocities of the right arm were computed for these frames.

Description of Sequence B (Fastest)

Figure 3, page 24, illustrates the tracings from Sequence B and Table II, page 25, presents the angular measurements taken from these tracings. Reference to these figure and table illustrations will be made throughout the description.

The sprinter assumed a medium crouch starting position with the left foot placed against the front block and the right leg extended with the right foot against the back block. The hips were raised slightly above the shoulders and the shoulders were slightly ahead of the starting line. The distance of the hips from the track was measured by drawing a vertical line through the greater trochanter mark and extending it down to the track. This distance measured on Frame 1 was 33.6 inches.

The angle of the right leg with the hip was 109 degrees and the angle at the knee was 168 degrees in Frame 1. The angle of the left leg with the hip was 39 degrees and at the knee was 110 degrees. The trunk was at a 24 degree angle with the horizontal and the head was at an angle of 159 degrees with the trunk. The angles of the right and left arm as measured at the elbow were 158 degrees and were considered to be the same for both arms because the arms were parallel in Frame 1.

From the head position in Frame 1, the runner's eyes appeared to be focused a few inches ahead of the starting line and the head was almost in line with the trunk. The weight of the body appeared to be shifted forward over the hands. The elbows were not locked prior to or during the start; the arms remained bent

at the elbows at the start and throughout the sprint. The sequential order of the start was again determined to be right arm, left arm, right foot, and left foot.

The start began with the initial movement of the right hand as the runner raised her arm and moved it up and back toward her body. The right arm was obstructed from view by the left arm and the trunk for the first .192 seconds of the start (through the 13th frame) and no measurements were taken until the right arm had passed the body and was on its way up and back.

Flexion of the left arm at the elbow began .096 seconds into the start as the arm was raised from the track. The left arm continued to drive forward for .192 seconds through Frame 19 at which time it began to drive back toward the body. The average time required for the left arm to complete its forward and backward drives throughout the sequence was .240 seconds.

The movement of the arms was in direct opposition to the movement of the legs as has been stated by experts. The right foot left the back block .112 seconds into the start or in Frame 7 and began to drive forward. This action paralleled the forward action of the left arm. The right leg completed its first step in the 25th frame, attaining an average velocity of 14.4 feet per second for the stride. At this time the left arm had already started to extend at the elbow to continue the momentum of the body parts.

The frame in which the front foot left the block was determined to be Frame 22 at which time the left foot had been

pushing against the block for .352 seconds. The angles at the knee and hip of the left leg were decreased rapidly at the time of the push-off and in the next few frames. The left knee was flexed 49 degrees between Frame 25 and 28, the average angular velocity being 1020.833 degrees per second.

As the left leg was driving forward, the right arm was moving forward also. The average time required for the right arm to complete its forward and backward movement throughout the sequence was .276 seconds.

The angle of the head with the trunk was held relatively constant throughout the start and five yard run, rarely fluctuating more than 15 degrees within a three frame period. There were eight instances in which the head was raised or lowered over 15 degrees within the three frames; the greatest change occurring .328 seconds into the start when the head was raised 31 degrees over the three-frame period. This occurred as the left arm was beginning to drive back toward the body (between frame 19 and 22) and the left leg was leaving the block. The push exerted by the left leg as it came out of the block could have caused this fluctuation.

The runner covered the five yard distance in four full strides; the final stride by the right leg not being completed as the runner crossed the five yard line. The distance of each of these strides and the average velocities for each were computed; the same perspective error correction was applied to the first stride as was described in Sequence A.

The distance of the first stride by the right leg was determined to be 50.9 inches and the average velocity was 14.4 feet per second. The second stride was executed by the left foot and covered a distance of 45 inches at an average velocity of 11.2 feet per second. The third stride by the right leg was also 45 inches and was performed at the same average velocity of 11.2 feet per second. The left leg executed the fourth stride which covered 58.2 inches at an average velocity of 14.4 feet per second. The length of the stride increased after the initial step by the right leg, although the length of strides two and three were equal in distance and in velocity. There was a 13.2 inch increase in stride length between stride three and four although both strides required .336 seconds to execute. Therefore, it can be concluded that the increase in length of stride alone resulted in the increase in velocity of stride between stride three and four.

When the arms were in the backswing and at their highest point, they consistently began their downward movement prior to the frame in which the same foot touched the track. This point is illustrated in Frames 34, 37, 55, 67 and 70 where the arm has already begun its forward motion as the foot touches the track. The left arm required .192 seconds to move forward as opposed to the .288 seconds required by the right leg. The right arm moved forward with the left leg and required .288 seconds; the left leg stride required .336 seconds. The left arm again drove forward with the right leg utilizing .240 seconds compared to the .336 seconds utilized by the right leg. In the last stride analyzed,

the right arm required .288 seconds and the left leg required .366 seconds. The times required to execute the last three strides were all the same, always being greater than the times required by the arm. The arms not only initiated the movement in the crouch start, but they seemed to lead the way for the legs and help maintain body momentum.

The right arm was consistently obscured from view by the body as it passed the body on its forward and backward motions; as a result no measurements or angular velocities for the right arm were computed for these frames.

Comparisons of Sequence A and Sequence B

Sequence A was selected as the slowest of the twelve starts based on the eighty-seven frames required to initiate and complete the five yard sprint. Sequence B was selected as the fastest because it only required eighty-four frames to complete the five yard run. Sequence A required .048 more seconds than Sequence B, resulting in a difference of .385 feet per second in the average velocity computation.

The starts were carefully analyzed to point out similarities and differences in execution. Because the two sequences have already been described, points referred to in these comparisons will be in reference to points already established in the preceding descriptions of Sequence A and B.

In both sequences the runner was instructed to assume a crouch start position. She placed the blocks eighteen inches

from the starting line and fifteen and one-half inches apart. The foot position was in agreement with the medium position as it was described in the definition found in Chapter I.

The suggested angles of the knees for the front and rear legs were mentioned in the Review of Literature, Chapter II. (3, 6, 7) The authors agree that the front knee should be at an angle near 90 degrees and the rear knee at an angle in excess of 90 degrees, probably somewhere between 110 degrees and 130 degrees.

The angle of the front knee in Sequence A was 122 degrees and in Sequence B was 110 degrees. The angle of the rear knee in Sequence A was 160 degrees and in Sequence B, it was 168 degrees. Although the runner positioned her starting blocks in the suggested manner, her body position was not in accordance with the suggested techniques. The larger angle assumed by the left (front) knee would cause the hips to be higher than was suggested. The position assumed by the runner was her preferred position.

Similarities

The analysis of both starts began with Frame 1, which is the frame prior to the first noticeable movement of the right hand. The vertical distance of the greater trochanter mark from the track was determined to be 33.6 inches for both starting positions. The spacing of the blocks remained the same for both starts and the fingers were placed on the track immediately behind the starting line for both starts. The sequential order of

movement for both sequences was the same, the initial action occurring with the raising of the right hand, followed by the left hand, right leg, and left leg. The arms remained flexed at the elbows prior to both starts and continued to be flexed throughout the runs.

The crouch start position of the body as measured by the angles were similar; the major variation coming with the angle of the head from the trunk. The angle at the trunk varied 6 degrees, the right leg at the knee 8 degrees, the left leg at the knee 12 degrees, the right leg at the hip 18 degrees, the left leg at the hip 4 degrees, the right arm at the elbow 4 degrees and the left arm at the elbow 4 degrees. Because the hips were raised the same distance in both starts and because these angles were so close, it was assumed the runner's position prior to the first movement was very similar and comparable. Figures 4 and 5, page 40, are actual photographs of the runner in Sequences A and B in Frame 1 prior to the first movement.

The movement of the right arm remained obscured from view .192 seconds into the start or through Frame 13 in both sequences, the right arm first becoming visable in Frame 16. The driving up and back of the right arm at this point appeared to be similar in both sequences, extending to a 157 degree angle in Sequence A and a 154 degree angle in Sequence B.

In both runs the left hand was raised from the track in Frame 6, .080 seconds after the right hand first moved. It

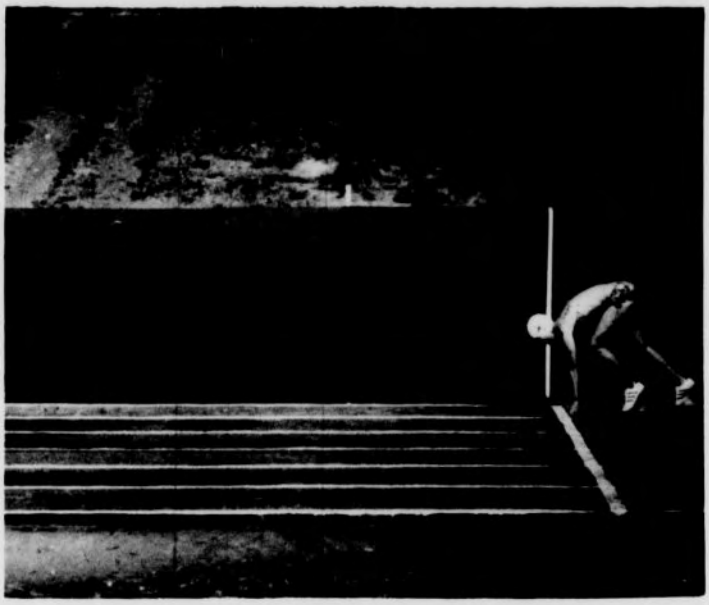

FIGURE 4

SEQUENCE A - FRAME 1

FIGURE 5

SEQUENCE B - FRAME 1

continued to drive forward through Frame 19, or for .192 seconds at which point it started to drive backward and extend at the elbow.

In both sequences, the right leg left the block .112 seconds into the start, approximately the same point at which the left hand was raised. Figures 6 and 7, page 42, show the right foot leaving the back block in Sequences A and B. To determine sequential order, the film was further analyzed and the left hand was first moved in Frame 6 in both sequences. The driving forward by the right leg was paralleled by the opposition action of the arms; in this instance by the left arm driving forward with the right leg.

In both sequences the left leg touched the track in Frame 43. In Sequence A, the leg had been driving forward .304 seconds as opposed to the .336 seconds in Sequence B. Even though the left foot touched the track at the same point in the sequence, there were other factors which had to be considered such as the length of the stride. Figures 8 and 9, page 43, show the left foot touching the track in Sequences A and B.

The number of full strides involved in both sprints was four, two occurring with the right leg and two with the left leg. After the first stride with the right leg, the length of the stride was decreased in both cases. The first stride was believed to be longer because it was able to utilize the push from both blocks. There was an increase in the length between strides three and four, and both fourth strides were measured at 58.2 inches. In

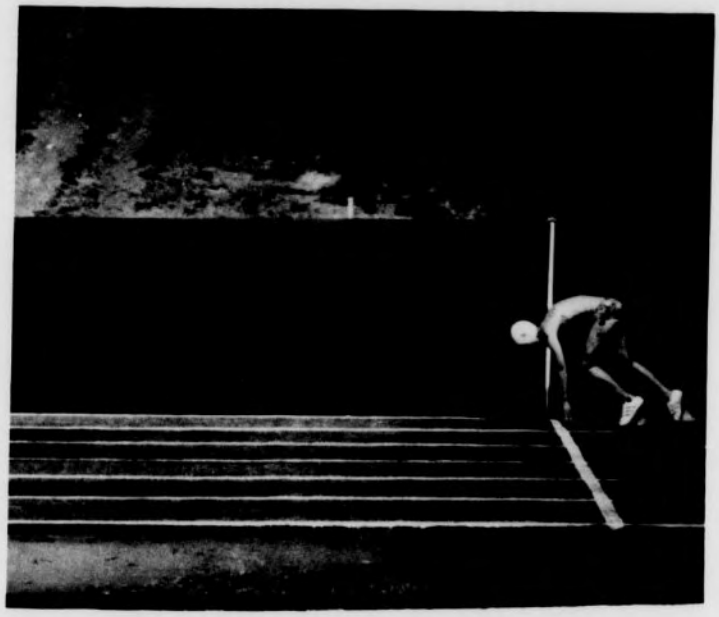

FIGURE 6

SEQUENCE A - RIGHT FOOT AS IT
LEAVES THE BLOCK FRAME 7

FIGURE 7

SEQUENCE B - RIGHT FOOT AS IT
LEAVES THE BLOCK FRAME 7

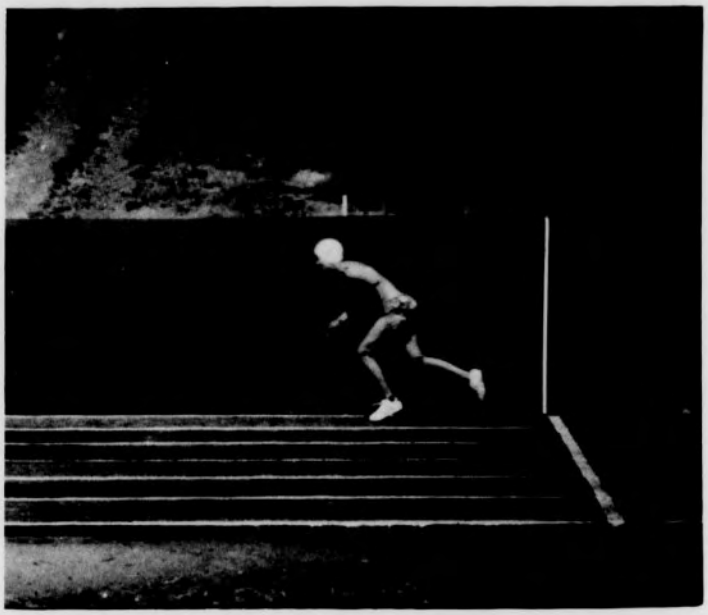

FIGURE 8

SEQUENCE A - LEFT FOOT AS IT
TOUCHES THE TRACK FRAME 43

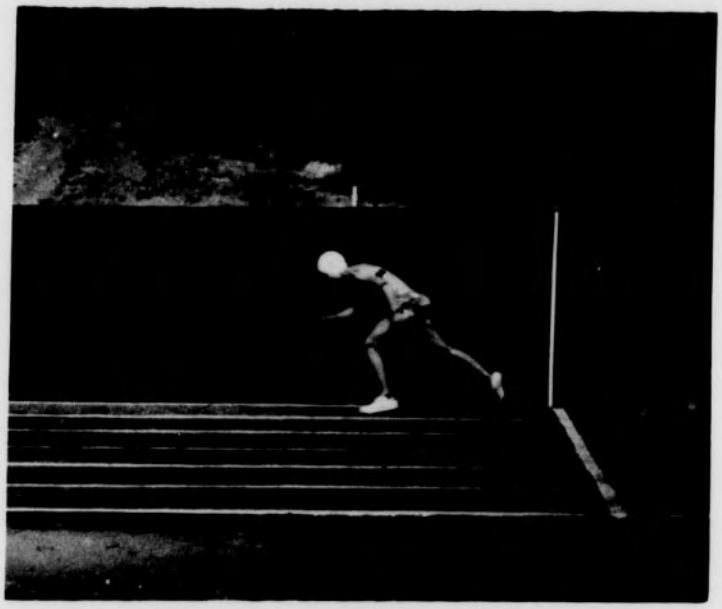

FIGURE 9

SEQUENCE B - LEFT FOOT AS IT
TOUCHES THE TRACK FRAME 43

both sequences, the right leg had been moving forward .224 seconds into the fifth stride when the runner passed the vertical line at the end of the run. The velocity of the body at this point was determined to be 19.5 feet per second in both sequences. In both sequences, the velocity of the stride decreased in the second stride and then evidenced an increase as the runner moved down the track.

The time required for the arms to complete their forward and backward drives was computed for each sequence. This involved two flexions and two extensions for each arm in each sequence. The average time required for the right arm to complete its flexion and extension was .276 seconds for both sequences. The right arm appeared to have been driving at similar speeds in both sequences. The changes in angles between the three-frame periods were checked and compared for both sequences and were also similar.

Differences

From the head position in Frame 1, the eyes in Sequence A appeared to be focused a short distance down the track; the angle of the head with the trunk was 133 degrees. In Sequence B, the eyes appeared to be focused a few inches ahead of the starting line and the angle of the head with the trunk was 159 degrees. The opinions stated by the experts regarding the position of the head during the start were varied. Five authors suggested the head should be in line with the back in the "get set" position. (3, 4, 7, 8, 9) In Sequence B, the head was close to this

position, the angle being 21 degrees from the suggested 180 degrees. However, one book stated the head should be down with the eyes looking directly at the track. (10) The high head position assumed by the runner in Sequence A was not suggested by any of the authors.

The opinions on where the eyes should be focused varied. Some authors stated the eyes should focus in front of the starting line (8, 10), and others stated they should be focused a short distance down the track. (4, 6, 7) The focus point of the eyes seems to be a matter of individual preference and is dependent on the position of the head.

In Sequence A, the head remained high as the right foot pushed off the block. At this point, the head in Sequence A was at 152 degrees and the head in Sequence B was 156 degrees. The fluctuation of the head in Sequence A was very similar to Sequence B, although the head was carried much higher throughout the five yard run in Sequence A. The head position in Sequence B seemed to not only remain lower but also stayed in line with the trunk. This can be ascertained by referring to the tracings and angle charts.

In Frame 1, the trunk was at a 30 degree angle with the horizontal in Sequence A and at a 24 degree angle in Sequence B. The hips were higher than the shoulders in this frame; therefore, the angle was measured by extending the trunk line ahead of the body until it met the horizontal line of the track. This procedure

was employed through Frame 16 in Sequence A, but was only necessary through Frame 13 of Sequence B. The trunk was raised at an average angular velocity of 120.833 degrees per second and required .240 seconds in Sequence A; it was raised 119.791 degrees per second and required .192 seconds in Sequence B. The runner was able to move into her running position sooner in the fastest start and maintained a lower body position with greater body lean throughout the five yard run in Sequence B.

The action of the arms was in direct opposition to the movement of the legs. The average time required for the left arm to complete its flexion and extension drives in Sequence A was .252 seconds; the time required in Sequence B was .240 seconds. The arm movements were further analyzed to determine the point where the left arm was moving with a greater velocity in Sequence B. This point was determined to be the point at which the left leg was driving forward in the second stride. The time required for the left arm to extend at the elbow and drive backward in Sequence B was .240 seconds. The time required for this same movement in Sequence A was .288 seconds.

The analysis of the leg movements was done on a stride basis. Figures 10 and 11, page 47, show the right foot touching the track in Sequences A and B. Figures 12 and 13, page 48, show the left foot leaving the block in Sequences A and B. The first stride was taken by the right leg as it left the blocks and drove forward. The distance of this step in Sequence A was

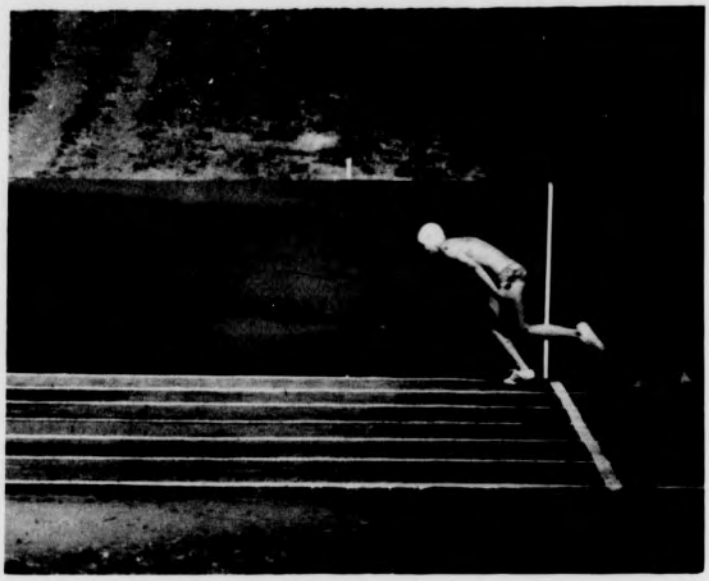

FIGURE 10

SEQUENCE A - RIGHT FOOT AS IT
TOUCHES THE TRACK FRAME 28

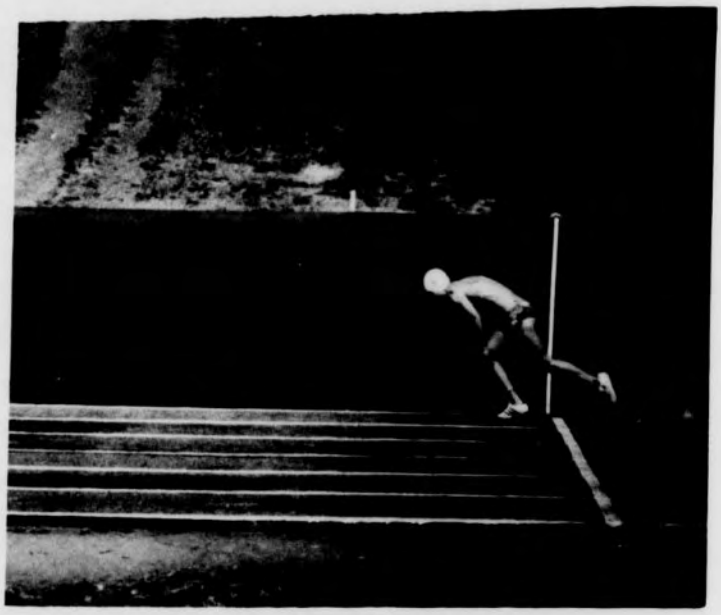

FIGURE 11

SEQUENCE B - RIGHT FOOT AS IT
TOUCHES THE TRACK FRAME 25

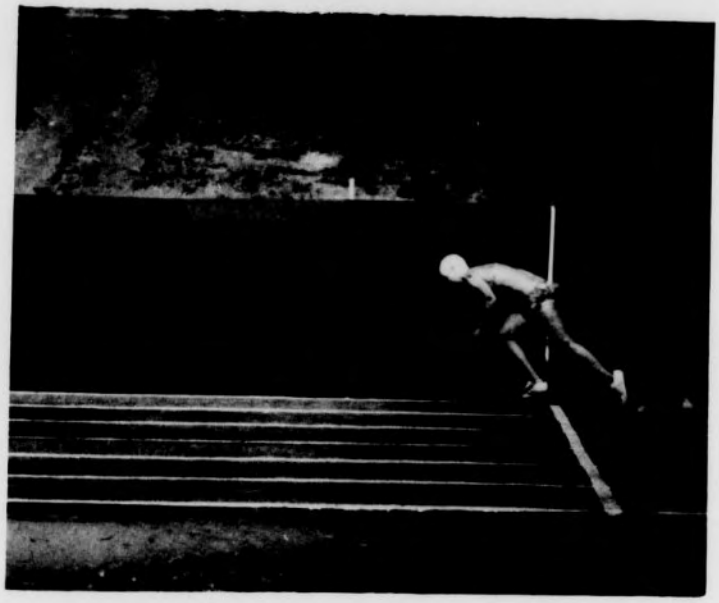

FIGURE 12

SEQUENCE A - LEFT FOOT AS IT
LEAVES THE BLOCK FRAME 24

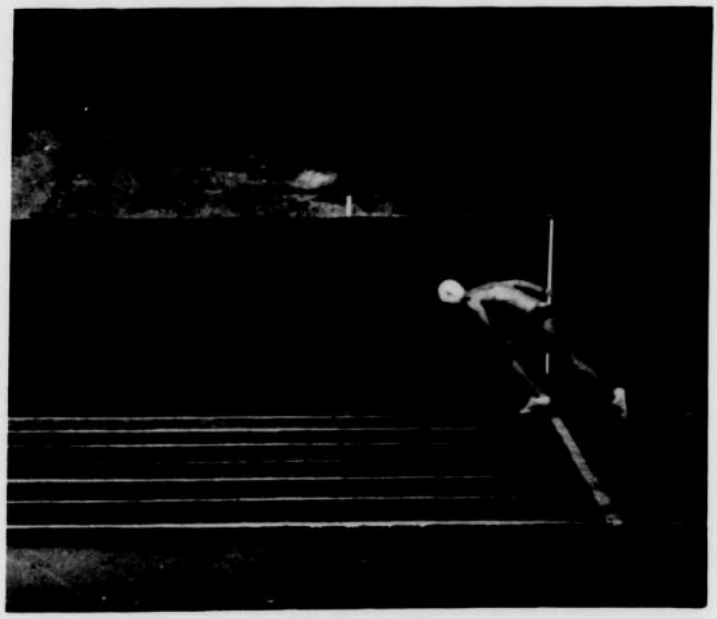

FIGURE 13

SEQUENCE B - LEFT FOOT AS IT
LEAVES THE BLOCK FRAME 22

48.5 inches and the average velocity was 11.9 feet per second. The distance of the first stride in Sequence B was 50.9 inches and was performed at an average velocity of 14.4 feet per second. The longer stride exhibited in Sequence B was recommended by three of the authors. (4, 8, 10) In Sequence A, the foot contacted the track .448 seconds into the start and touched the track 13.2 inches ahead of the starting line. The time required in Sequence B was .400 seconds and the distance of the foot in front of the starting line was 15 inches. Parker and Kennedy suggested the foot touch the track 12 inches ahead of the starting line. (6:17-24) Foreman and Husted suggested the distance should be 24 inches. (3:34-38) The distance appears to be a personal matter. However, this runner was able to obtain a greater average velocity in the Sequence B, where the stride was longer.

The length of the second stride with the left leg in Sequence A was 33.6 inches and involved .304 seconds. The length of stride in Sequence B was a greater distance and required a longer time to execute. However, the left foot pushed off from the block .384 seconds into the start in Sequence A and .352 seconds into the start in Sequence B. The runner has already gained .032 seconds in Sequence B; the right foot has touched the track sooner and the left leg has pushed off from the block sooner.

The third stride involved a greater distance and velocity as it was performed in Sequence A. The distance traveled by the right leg was 46.8 inches and the velocity was 11.6 feet per

second. The right leg in Sequence B covered 45 inches and maintained the velocity of 11.2 feet per second exhibited in stride 2.

The distance of the fourth stride was the same for Sequence A and B; however, the velocity attained in Sequence B was greater than Sequence A. This velocity was 14.4 feet per second for Sequence B and 12.6 feet per second for Sequence A. Apparently, the left leg was driving forward with greater force and speed in Sequence B.

Because the last step by the right leg was not completed in either sequence, the average angular velocities were not computed. The right leg had been moving forward fourteen frames, or .224 seconds in both sequences, as the greater trochanter mark passed the vertical line. However, the right leg in Sequence B was further along in the stride and was about to touch down on the track. This was illustrated in the stick figure tracings (Figures 2 and 3, pages 21 and 24) and can also be pointed out by comparing the angles of the right hip and knee. In Sequence B, the angle at the right knee was 10 degrees greater than the angle in Sequence A. This implied the right leg was extending farther at the knee in Sequence B as it prepared to touch the track. The angle of the right leg with the hip was 11 degrees smaller in Sequence B, implying that the right knee was raised higher. A high knee lift is advocated by experts when running sprints. It is not known whether this aided the runner in this particular sprint.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The purpose of this study was to analyze and compare mechanical differences in the execution of the fastest and slowest of twelve crouch starts at a five yard distance as they were executed by a woman sprinter. The analysis of the starts was concerned with the sequential order of movement and with the various velocities and angles of body parts during the start and the first five yards.

The starts were executed by one experienced woman sprinter from the Graduate School at the University of North Carolina at Greensboro. The sprinter had previously competed as a member of a high school track team and as a member of a college track team.

The filming was done on the track in front of a backdrop which was twenty-one feet long and five feet high. Vertical lines on the backdrop marked the starting line and the finish line for the five yard distance. Camera speed was calculated prior to the filming by dropping a shot a known distance. The average camera speed was calculated to be 61.6 frames per second. The height of the backdrop was used to provide a conversion factor in order to properly scale the measurements on the projected film. The calculations were made in accordance with the method described by Cureton. (11)

The filming was done with a Bolex H16 sixteen mm spring driven motion picture camera equipped with a 25mm lens. The film used was positive type 7276. The camera was mounted on a tripod five feet above the ground and was placed sixty feet six inches from the center and perpendicular to the twenty-one foot filming area.

The subject was dressed in a two-piece swimming suit, tennis shoes, and a white swimming cap. Reference points were placed on the body with a black water color felt tip pen. The head, left wrist, left elbow, left shoulder, greater trochanter of the left leg, left knee, and left ankle were marked on the lateral side of the left side of the body. The right ankle, knee, wrist, and elbow were marked on the medial side of the right leg and arm.

The subject placed her starting blocks with the front block fixed at a point eighteen inches behind the starting line and the distance between her feet was fifteen and one-half inches. The filming was done from the left side of the sprinter to allow the best shot of the left leg which maintained contact with the block the longest time. The sprinter executed twelve starts and ran past the end of the backdrop, but only the start and the first five yards of the sprint were filmed.

The film was viewed on a Magnasync Moviola 16 mm Table Viewer and the slowest and fastest starts were selected based on the number of frames. The slowest sequence consisted of 87 frames; Frame 1 being the frame prior to the initial movement of the right

hand and Frame 87 being the frame in which the greater trochanter mark passed the vertical five yard tape mark on the backdrop. The same method was used to determine the fastest start; eighty-four frames were contained in this sequence.

The stick figure tracings for the first frame and every third frame thereafter were traced from each sequence. Because the number of frames in the sequences were not evenly divisible by three, the last measurement frame was two frames from the previous measurement frame.

The angles formed at the elbows, knees, legs at the trochanter marking, the angle formed by the head and the trunk, and the angle of the trunk with the horizontal were measured with a protractor. The length of stride was determined by measuring to the nearest thirty-secondth of an inch. Average angular velocities were computed for each stride as well as for the raising of the trunk during the first portion of the start. Average velocities were also computed for all changes in the angles for all body markings for the start and five yard run.

Conclusions

The analysis revealed a high head position in the slowest start as compared with the fastest sequence in which the head was kept low and in line with the trunk. The runner maintained a lower body position after the first stride in the fastest start and moved into this position sooner. The body position in the slowest sequence was more upright throughout the run and paralleled the high head position.

The length of the first stride out of the blocks was longer in the fastest start and was executed with a greater velocity. The velocity and distance of the second stride out of the blocks was also greater in the fastest start. The average velocity of the left arm was greater in the fastest start and appears to have been driving much harder. The average right arm velocities were the same for both starts.

Recommendations

In light of the results of this study and of the information available in track and field books for women, it is recommended that further research be done in the area of the crouch start for women. The comparison of the fastest and slowest of a series of starts seems to be an effective approach. However, when analyzing the film, it is suggested significant frames be selected for analysis as well as every third frame. The points at which the feet left the blocks and touched the track were significant points and it is important that exact measurements be made. The use of more subjects utilizing different types of starts would help validate the conclusions of this study. It is also possible that the distance of the run be increased and timing devices be used at predetermined spots throughout the run to attempt to pinpoint the exact point at which the time change occurred.

When conducting a study of this type, it is recommended that some type of finish line be used to motivate the runner to complete the entire sequence at her maximum speed. The marking

at the shoulder should be placed in a position which would provide an unobstructed view at all times, regardless of the rotation of the arm. Another camera positioned on the other side of the runner would allow measurements to be taken in the frames where the right arm was obscured from view. This would also provide an opportunity to mark the greater trochanter on the opposite side and would serve as a checkpoint for determining distances and velocities as well as body lean.

BIBLIOGRAPHY

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A. BOOKS

1. Bunn, John W. Scientific Principles of Coaching. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1955.

2. Doherty, J. Kenneth. Modern Track and Field. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1963.

3. Foreman, Ken, and Virginia Husted. Track and Field Techniques for Girls and Women. Dubuque, Iowa: Wm. C. Brown Company, Inc., 1965.

4. Jackson, Nell C. Track and Field for Girls and Women. Minneapolis, Minnesota: Burgess Publishing Company, 1968.

5. Miller, Kenneth D. Track and Field for Girls. New York: The Ronald Press Company, 1964.

6. Parker, Virginia, and Robert Kennedy. Track and Field for Girls and Women. Philadelphia: W. B. Saunders Company, 1969.

7. Pugh, D. L., and D. C. V. Watts. Athletics for Women. London: Stanley Paul and Company, LTD., 1965.

8. Scott, Phebe, and Virginia R. Crafts. Track and Field for Girls and Women. New York: Appleton-Century-Crofts, 1964.

9. Thompson, Donnis Hazel. Women's Track and Field. Boston: Allyn and Bacon, Inc., 1969.

10. Wakefield, Frances, Dorothy Harkins, and John M. Cooper. Track and Field Fundamentals for Girls and Women. St. Louis: C. V. Mosby Company, 1970.

B. PERIODICALS

11. Cureton, T. K. "Elementary Principles and Techniques of Cinematographic Analysis as Aids in Athletic Research," The Research Quarterly, X (May, 1939), pp. 3-24.

12. Cureton, T. K. "Mechanics of the Track Racing Start," Scholastic Coach, 4:14-16, January, 1935.

13. Deshon, Deans E., and Richard C. Nelson. "A Cinematographical Analysis of Sprint Running," The Research Quarterly, 35:451-455, December, 1964.

14. Dickinson, A. D. "The Effects of Foot Spacing on Starting Time and Speed in Sprinting and the Relation of Physical Measurement to Foot Spacing," The Research Quarterly, 5:12-19, 1934.

15. Henry, Franklin. "Force-Time Characteristics of the Sprint Start," The Research Quarterly, 23:301, October, 1952.

16. Kistler, J. W. "A Study of the Distribution of the Force Exerted Upon the Blocks in Starting the Sprint from Various Starting Positions," The Research Quarterly, 5:27-32, March, 1934.

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

C. UNPUBLISHED MATERIALS

18. Hulstrand, Bonnie Jean. "The Effect of the Pelvic Width Relative to Lateral Foot Placement on the Success of the Sprint Start for Women." Unpublished Master's thesis, Washington State University, Pullman, 1965.

19. Lanier, Louis L. "A Comparison of Techniques of Determining Velocity in the Track Sprint Start." Unpublished Master's thesis, The University of Alberta, Canada, 1968.

20. Rozzi, Louise Maria. "A Cinematographia Analysis of the Lacrosse Cradle." Unpublished Master's thesis, University of North Carolina, Greensboro, 1969.

APPENDIX

TABLE III

AVERAGE ANGULAR VELOCITIES FROM SEQUENCE A (SLOWEST)

Frame	Trunk with Horizontal	Head with Trunk	Right Leg at Knee	Left Leg at Knee	Right Leg at Hip	Left Leg at Hip	Right Arm at Elbow*	Left Arm at Elbow
4	20.833	187.5	187.5	104.166	125.0	145.833	-	83.333
7	250.0	583.333	83.333	104.166	208.333	437.5	-	270.833
10	104.166	187.5	416.666	125.0	104.166	20.833	-	62.5
13	187.5	166.666	812.5	83.333	250.0	354.166	-	541.666
16	41.666	187.5	375.0	104.166	291.666	187.5	-	708.333
19	125.0	250.0	145.833	354.166	375.0	395.833	62.5	354.166
22	104.166	83.333	104.166	625.0	125.0	604.166	20.833	125.0
25	104.166	83.333	500.0	375.0	270.833	**	-	854.166
28	104.166	187.5	208.333	833.333	520.833	145.833	-	750.0
31	312.5	62.5	833.333	520.833	1229.166	41.666	-	229.166
34	83.333	229.166	375.0	312.5	20.833	479.166	208.333	562.5
37	41.666	41.666	541.666	458.333	354.166	395.833	333.333	83.333
40	20.833	229.166	**	458.333	83.333	41.666	520.833	125.0
43	187.5	291.666	479.166	62.5	20.833	166.666	958.333	104.166
46	166.666	166.666	875.0	166.666	708.333	250.0	-	479.166
49	125.0	437.5	62.5	270.833	833.333	229.166	-	395.833
52	**	250.0	562.5	104.166	500.0	270.833	-	20.833
55	187.5	166.666	458.333	604.166	62.5	750.0	41.666	312.5
58	20.833	62.5	375.0	395.833	125.0	62.5	41.666	1083.333
61	**	62.5	229.166	895.833	416.666	333.333	-	395.833

* No measurements are recorded when the right arm was obscured from view.
** No change in angle evidenced in the tracings.

TABLE III (continued)

Frame	Trunk with Horizontal	Head with Trunk	Right Leg at Knee	Left Leg at Knee	Right Leg at Hip	Left Leg at Hip	Right Arm at Elbow*	Left Arm at Elbow
64	166.666	125.0	479.166	625.0	1125.0	437.5	-	166.666
67	125.0	291.666	62.5	104.166	250.0	104.166	770.833	500.0
70	41.666	208.333	208.333	41.666	354.166	625.0	729.166	83.333
73	104.166	500.0	187.5	604.166	416.666	104.166	354.166	333.333
76	62.5	83.333	875.0	645.833	375.0	62.5	875.0	145.833
79	41.666	125.0	791.666	20.833	395.833	375.0	-	20.833
82	83.333	187.5	583.333	104.166	895.833	395.833	-	750.0
85	104.166	708.333	125.0	62.5	437.5	83.333	-	583.333
87	93.75	437.5	531.25	781.25	250.0	656.25	125.0	218.75

* No measurements are recorded when the right arm was obscured from view.

TABLE IV

AVERAGE ANGULAR VELOCITIES FROM SEQUENCE B (FASTEST)

Frame	Trunk with Horizontal	Head with Trunk	Right Leg at Knee	Left Leg at Knee	Right Leg at Hip	Left Leg at Hip	Right Arm at Elbow*	Left Arm at Elbow
4	20.833	375.0	62.5	62.5	145.833	125.0	-	83.333
7	125.0	312.5	145.833	41.666	62.5	208.333	-	83.333
10	250.0	62.5	500.0	20.833	**	333.333	-	166.666
13	83.8333	41.666	479.166	145.833	62.5	333.333	-	541.666
16	104.166	**	520.833	83.333	645.833	270.833	-	604.166
19	145.833	520.833	104.166	375.0	145.833	479.166	20.833	479.166
22	**	645.833	291.666	437.5	187.5	312.5	270.833	437.5
25	145.833	250.0	416.666	354.166	333.333	83.333	-	1250.0
28	187.5	145.833	62.5	1020.833	375.0	250.0	-	708.333
31	83.333	229.166	812.5	375.0	1020.833	166.666	1250.0	500.0
34	20.833	145.833	333.333	187.5	458.333	645.833	145.833	187.5
37	20.833	583.333	125.0	395.833	83.333	270.833	416.666	250.0
40	20.833	375.0	166.666	541.666	125.0	20.833	250.0	83.333
43	**	83.333	937.5	125.0	312.5	333.333	1145.833	708.333
46	104.166	291.666	625.0	83.333	666.666	145.833	-	854.166
49	62.5	208.333	354.166	250.0	458.333	458.333	-	479.166
52	20.833	458.333	20.833	416.666	541.666	520.833	416.666	854.166
55	41.666	62.5	375.0	83.333	41.666	83.333	83.333	770.833
58	20.833	229.166	729.166	770.833	312.5	229.166	-	562.25
61	208.333	291.666	83.333	666.666	1041.666	625.0	-	62.5

*No measurements are recorded when the right arm was obscured from view.
**No change in angle evidenced in the tracings.

TABLE IV (continued)

Frame	Trunk with Horizontal	Head with Trunk	Right Leg at Knee	Left Leg at Knee	Right Leg at Hip	Left Leg at Hip	Right Arm at Elbow*	Left Arm at Elbow
64	229.166	62.5	729.166	291.666	520.833	354.166	-	416.666
67	62.5	104.166	312.5	104.166	500.0	583.333	562.5	312.5
70	20.833	145.833	41.666	770.833	41.666	41.666	-	**
73	**	458.333	833.333	187.5	145.833	187.5	479.166	62.5
76	83.333	208.333	604.166	208.333	541.666	437.5	-	208.333
79	62.5	250.0	187.5	208.333	833.333	208.333	-	541.666
82	83.333	395.833	875.0	229.166	604.166	416.666	104.166	333.333
84	93.75	31.25	343.75	781.25	281.25	625.0	187.5	31.250

*No measurements are recorded when the right arm was obscured from view.
**No change in angle evidenced in the tracings.

DATA ON SUBJECT USED IN STUDY

Height of subject: 67 3/4 inches (measured in her tennis shoes)

Weight of subject: 128 pounds

Measurement of reference points:

Left side of body
- Ankle to knee 16½ inches
- Knee to trochanter 14½ inches
- Wrist to elbow 10 inches
- Elbow to shoulder 10½ inches

Right side of body (as measured on the inside)
- Ankle to knee 16 inches
- Wrist to elbow 10 inches

Number of frames involved in twelve starts:

Sequence	Number of Frames
1	87
2	87
3	87
4	84
5	86
6	87
7	85
8	87
9	85
10	87
11	85
12	86