A FILM ANALYSIS OF TOE-HEEL ACTION DURING GROUND CONTACT OF WOMEN RUNNERS

A Thesis

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

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TO THE MEMORY OF MY FATHER

DR. WARREN H. YOULE

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CHAPTER I

ORIENTATION TO THE STUDY

Introduction

Man, because of his physical structure, has run throughout history. The earliest records reveal man running for food, for joy, and for his very life. Running has been an essential part of man's natural heritage, and not until recently has any attention been devoted to how man runs.

Running is a combination of beauty, grace, power, confidence, rhythm and skill, and a way of obtaining and maintaining physical fitness. During the past two to three decades many of the women in competitive track have been slender, graceful girls. During the 1960 Olympic Games when Wilma Randolph won two gold medals for the United States, the grace and beauty of her running form accomplished much in promoting track for girls and women of all ages and skill levels.

An analysis of the mechanics involved in running includes the action of arms, positions of the trunk, action of the legs, and actions of the foot.[1] Upon reviewing the literature concerning actions of the foot, the investigator found

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[1]Nell C. Jackson, Track And Field For Girls And Women (Minneapolis: Burgess Publishing Company, 1969), p. 25.

few studies conducted concerning the toe-heel action during contact with the ground. Many authors, when discussing running form, make no mention of foot action during contact with the ground other than to state that the toes should be pointed straight ahead when the foot touches the ground. Parker and Kennedy,[1] Bresnahan,[2] and Hildreth,[3] are only a few of the authorities who do not note specific foot action during ground contact.

The majority of writers who make mention of specific toe-heel action during ground contact report that the ball of the foot should touch down first. Nell Jackson,[4] a leading authority in women's track and field, states that the body weight is first taken on the ball of the foot with the heel making contact either not at all or only momentarily depending upon the distance of the run. Bunn,[5] in agreement with Jackson, bases his beliefs upon the mechanical principles involved. He reports that the runner who permits his heel to

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[1]Virginia Parker and Robert Kennedy, Track and Field for Girls and Women (Philadelphia: W. B. Saunders Company, 1969).

[2]George Bresnahan, W. W. Tuttle, and Francis Gretzmeyer, Track and Field Athletics (St. Louis: The C. V. Mosby Company, 1964).

[3]Peter Hildreth, How To Train For Track And Field (New York: ARC Books, Inc., 1965).

[4]Jackson, Track And Field For Girls And Women, p. 25.

[5]John W. Bunn, Scientific Principles of Coaching (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1955), p. 111.

touch the ground first causes his center of gravity to fall behind the contacting foot. The runner is thus slowed down and additional forces must be exerted in order to overcome deceleration. Bunn states further that when the heel of the foot lands first, jarring is avoided and quick ankle extension is permitted.

A conflicting theory concerning foot action is presented by Haney,[1] a contemporary authority in track. He states that in all distance runs the heel contacts the ground first and is immediately followed by the toe. According to Haney, the leg muscles do not become as tired or sore when the heel is allowed to touch first as is the case if the toe contacts the ground first.

The investigator found no cinematographic research conducted on women runners with respect to toe-heel action during ground contact and only one study related to the foot action of men runners during ground contact has been reported. It is a purpose of this study to determine the manner in which the foot is placed on the ground by women runners in selected track events. It is an aim of this study to add to the available literature concerning form in running and to enhance the teaching and coaching techniques of successful foot mechanics. Hopefully, this investigation will determine if there is any relationship between the distance of the run and toe-heel action during ground contact. The investigator hopes to motivate others to pursue similar studies.

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[1]George E. Haney, "What About Stride," Athletic Journal, Vol. XLVIII (Fall, 1968), pp. 13-15, 38-39.

Statement of the Problem

The study was conducted to determine the relationship between running speed and toe-heel action during ground contact through analysis of film records of highly skilled women runners competing in selected national track events.

Definitions and/or Explanations of Terms

For the purpose of clarification, the following explanations and/or definitions of terms have been established for use in the study:

A. Cinematography: The investigator accepts the following definition and explanation. "Cinematography is the art or science of motion-picture photography."[1] For the purpose of this study the investigator includes in the definition of "cinematography" the analysis of the photography.

B. Toe-Heel Action: For the purpose of this study, the term "toe-heel action" will refer to action of the foot during ground contact. Particular attention will be paid to which part of the foot makes initial contact with the ground.

C. Ground Contact: For the purpose of this study the term "ground contact" will refer to the amount of time (or number of frames of film) during which the foot is in contact with the ground.

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[1]Webster's Third New International Dictionary, Third Edition, 1968.

D. Highly Skilled: For the purpose of this study the investigator defines "highly skilled" as those women competing in the selected running events of national track meets in the United States.

Purposes of the Study

The general purpose of the study was to determine, through cinematography, the toe-heel action during ground contact of women runners competing in national track meets. The specific purpose of the study was to determine the relationship of the toe-heel action during ground contact in the following events: (1) the mile run, (2) the 880 yard run, (3) the 440 yard dash, (4) the 220 yard dash, and (5) the 100 yard dash. The investigator analyzed film data of fifteen women runners who competed in each of the five events.

Delimitations of the Study

The present study was subject to the following delimitations:

1. The cooperation of the directors of the selected track meets throughout the United States.
2. The analysis of foot action of fifteen women runners who were competing in the selected track events.
3. The extent to which the subjects were representative of the population from which they were drawn.
4. The selected equipment which was used in the filming and in the analysis of the film.

5. The extent to which the camera speed was accurate as no clock or other timing device was used.
6. Filming of the competitors at sixty-four frames per second with the camera at ground level and approximately nine feet from the track edge and with the camera lens aligned parallel to the ground.
7. Analysis of the point-and-line drawings of selected frame from the film of each subject.

Summary

Few studies have been conducted on the runner's toe-heel action during ground contact. The investigator found no cinematographic studies conducted on women runners' toe-heel action during ground contact and only one study related to men's toe-heel action during ground contact. Currently, there are three conflicting theories presented by one or more authors regarding the runner's foot action during contact. A majority of writers state that in all running events the ball of the foot contacts the ground first. One contemporary authority has presented the theory that the heel of the foot lands first in all distance runs. The third supposition regarding the foot action during ground contact is that the distance of the run determines the manner in which the foot is placed on the ground.

The purpose of the present investigation was to determine, through cinematography, the toe-heel action during ground contact of women runners competing in national track meets. Specifically, the investigator sought to determine the

relationship between toe-heel action and each of the following events: (1) the mile run, (2) the 880 yard run, (3) the 440 yard dash, (4) the 220 yard dash, and (5) the 100 yard dash. The investigator collected film data of fifteen runners competing in each of the five running events during actual competition.

Chapter II presents the review of literature that was found pertinent to this investigation.

CHAPTER II

RELATED LITERATURE

A survey of the literature disclosed that the present study did not duplicate any previous investigations with respect to scope and content. A review of the studies which were related to the present study and were of benefit to the development of this study are presented.

Nett[1] conducted a cinematographic study of the best German runners in order to determine the exact method by which the foot was planted. Nett's purpose was to settle the controversy between many famous coaches as to whether all runners planted the heel first or the toe first. Another aim of Nett's study was to determine whether the method of foot plant was determined by the distance of the race.

All subjects were filmed without their knowledge during actual competition in track meets. The camera was approximately twenty to thirty centimeters from the ground, with the camera lens as nearly parallel to the ground as possible. The films were taken at sixty-four frames per second, and the races filmed ranged from the 100 meter event to the marathon event.

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[1]Toni Nett, "Foot Plant in Running," Track Technique, Vol. XV (March, 1964), pp. 462-464.

Two separate sets of results were indicated by the analyses of the films. Nett's first conclusions were drawn solely upon the naked-eye-viewing of the films. They are as follows: (1) runners at all distances plant the foot on the outside edge; (2) the point of contact of the foot with the ground is different according to the speed of running; and (3) at all distances beyond 1500 meters and up to the marathon, initial contact with the ground is made with the outside edge of the foot between the heel and the metatarsus.

Nett's second set of conclusions made from analyses of the film data were as follows: (1) in sprinting the "active" or "dynamic ball-plant" makes a fast pace possible, but energy consumption is great; (2) in middle distance running (800-1500 meters) the "metatarsal plant" requires less strength than does the foot plant used in sprinting; (3) in endurance running the heel-metatarsus plant is used, which requires less expenditure than either of the forms used for the middle distance runs or the sprints; (4) foot-plant is closely related to the distance of the race and the pace; and (5) foot plant is almost independent of the type of runner as the laws of running are based upon the rate of speed.

Deshon and Nelson undertook a study to examine, through cinematography, the relationship between speed of running and the following variables: (1) the length of two strides (a

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[1]Deane E. Deshon and Richard C. Nelson, "A Cinematographical Analysis of Sprint Running," Research Quarterly, Vol. XXXV, No. 4 (December, 1964), pp. 451-455.

cycle); (2) the angle that the leg is raised in front of the body; and (3) the angle of the leg with the ground at touchdown. The nineteen male subjects used for the study consisted of ten track sprinters and nine baseball players from the University of Maryland. Each participant was asked to run twenty-five yards to build up to maximum speed prior to entering the fifteen yard filming zone.

The film data were collected by means of a sixteen millimeter Bolex Camera with a thirty-five millimeter lens. The camera speed was set at sixty-four frames per second and the lens was set between f: 4.0 and f: 5.6. The filming was taken approximately 155 feet from and perpendicular to the center of the fifteen yard filming zone.

The films were projected on a Bell and Howell motion analysis projector. Each frame, kept horizontally and vertically perpendicular to the wall, was analyzed and the various measurements were transferred onto graph paper.

The data from the film analyses were statistically treated and the results were presented in tabular form. The initial results were concerned with intercorrelations between all the variables. The graphs revealed all correlations to be linear. Significant relationships at the .05 level occurred between the following: (1) mean length of cycle and mean angle of leg lift, (2) mean length of cycle and mean angle of leg at touchdown, (3) velocity and mean length of cycle, (4) velocity and mean angle of leg lift, and velocity and mean angle of leg at touchdown. No significant relationship at the .05

level occurred between the mean angle of leg lift and the mean angle of leg at touchdown.

Deshon and Nelson's second set of results included the relationship between each runner's speed (through each cycle) and the three variables. A significant relationship ($P < .01$) was found between mean length of cycle and mean angle of leg at touchdown. The third measure, mean angle of leg lift, revealed no significant correlation coefficient.

In conclusion, the authors state that a high knee lift, long running stride, and placement of the foot close beneath the center of gravity have a great effect upon efficient running. It would be an overestimation, however, to conclude that these factors cause the runner to be faster. Further research is needed to determine the extent of influence these factors have upon speed and other variables need to be investigated as to their relationship to speed.

Bosen,[1] in his article concerning foot placement in running, revealed the basic differences between distance running and sprinting. Although he states that form is unquestionably individualistic in style, foot placement should be governed by certain mechanical principles. The efficient runner should adhere to these basic principles in order to be successful.

According to Bosen, the old technique of running did not allow the heel to contact the ground. It was believed

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[1]K. O. Bosen, "Foot Placement in Running," Track Technique, Vol. XXXVIII (December, 1968), p. 1207.

that the runner who touched his heel on the ground was delayed both in speed and effort. More recent trends have permitted heel contact during distance runs but not in sprinting. It has been discovered, however, that a light settling on the heels allows for additional ankle flexion and bounce in sprinting while energy is conserved for the drive phase of the leg action.

Bosen states that heel contact in the distance run is longer than in the sprint because economy of effort, characterized by less driving effort, is the prime consideration in distance running. More force must be exerted in the direction of the progress in sprinting; therefore, the foot placement is a quick ball-heel-toe action. Visual appraisal of the sprinter's bounce and rapid foot movement leads one to believe that the heel never touches the ground. Total body weight, however, is momentarily applied on the heel as it contacts the ground while the center of gravity is being moved forward for the next stride.

Bosen further states that the successful mechanics of running include the movement of the body's center of gravity in a horizontal direction. One factor which increases the velocity of this continuous movement is the amount of decrease in the angle of the leg as it makes contact with the ground. In order to decrease this angle, the pelvis must be carried low to allow for greater flexion of the driving knee, a more powerful thrust of the driving leg knee, and a longer stride.

In order to minimize the shock of impact as the foot touches the ground, the contact is made with a downward, backward action, in order that the ball of the foot may touch first. It is not only harmful to the athlete's muscles if the heel is allowed to touch the ground first, but the center of gravity falls behind the foot causing deceleration.

Duration of the heel contact with the ground is the basic difference between distance running and sprinting. The distance runner must conserve effort while the sprinter must utilize a strong driving power and a short reaction time. In the middle and distance runs, therefore, the heel is in contact with the track longer than it is in the sprint events.

In a report written by Haney,[1] certain stride characteristics were given for each running event. The author states that although it may prove harmful for a coach to modify a runner's natural stride, failure to execute certain basic movements may cause a loss of efficiency.

Haney submits that running form is greatly dependent upon body build. Foot, leg, and shoulder structure affect the type of movement which the runner will execute. Haney clarifies that the running form standards to which he adheres are geared to the boy with average body structure. Any effort to conform a boy with an atypical body structure to Haney's style of stride will result in muscle soreness, loss of balance, and an uncertain stride.

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[1]Haney, "What About Stride."

According to Haney, the distance form is the most natural of all the running forms. While boys are growing up they are constantly running. The author contends that most boys run flat-footed and will never run on the toes unless told to. Children who run barefooted develop a light touch and those who run in shoes run on the heel because of the protection of the shoes. The heel-toe action, therefore, is the most natural and the most successful running form for the distance runs.

Running on the toes requires the extensor muscles to ease the foot down on contact as well as to operate during the push-off. The leg becomes tired much quicker if the toe touches first than if the heel contacts the ground first.

Haney states that distance running form includes the following: (1) heel-toe action upon ground contact, (2) legs swung rather than driven, (3) toes pointed straight ahead with no crossing over, (4) knees recovering straight ahead, (5) knees and ankles fully extended at push-off, (6) high knee action, (7) relaxed body, (8) low carriage of the arms, (9) a comfortable forward lean, and (10) relaxed but not "paddling" wrists with thumb side on top.

A few of the common errors Haney has discovered in running include: (1) toeing out or in, (2) shoulder swing, (3) side wobble, (4) excessive forward or backward lean, (5) kicking too high behind, (6) poor arm action, and (7) shortness of breath.

Haney further states that middle distance running (440-yard, 880-yard, and sometimes the mile) requires a smooth

but faster pace than the distance runs. The main differences include more body lean, higher leg swing, and more pronounced arm action. The ball of the foot touches before the heel.

Maximum speed, according to Haney, the main characteristic of sprinting, requires total body efficiency. The most obvious difference between middle-distance running and sprinting are the high pointed knees, lack of back arch, and a more pronounced driving action of the arms. Running with high knees enables the body to travel further before the next stride. The straight, downward thrust of the feet begins a new stride before the momentum of the last one has ended. The toes should be pointed down toward the track and at the instant of contact the foot presses down flat but not stiffly. An instantaneous hard thrust should occur at the end of the stride. Interestingly enough, the sprinting strides are longer than middle distance strides, and the distance stride is the shortest of the three.

According to Wilt,[1] the present concept of the term "sprint" includes all runs below 880 yards. In his article he states that through proper training one can coordinate the power of needed muscle groups in order to improve speed.

Through training, according to Wilt, a runner learns to discard unnecessary movements while strengthening efficient movements. Increasing stride length and cadence will improve a runner's speed. The natural way to increase an individual's

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[1]Fred Wilt, "Notes on Sprinting," Track Technique, Vol. XVII (September, 1964), pp. 533-536.

stride length is by developing muscular strength, joint mobility, and elasticity. Mechanically, stride length may be increased by the thrust of the leg against the ground, acting behind the runner's center of gravity. Propulsion of the runner is caused by forceful extension of the hip, knee, and ankle joints of the contact leg while the recovery leg pulls forward quickly and forcefully.

Wilt states that in the sprint events, the foot should be pointed straight ahead in order that the runner may travel in a straight line. Contact of the foot is first made with the outer edge of the ball of the foot followed by the heel which touches momentarily. The knee should be bent as the foot contacts the ground. The heel is then lifted and the hip, knee, and ankle are extended. The body is propelled by the forward movement of the center of gravity.

In reference to the American concept that the Finns allow the heel to contact the ground first, Wilt[1] reported that Finland's Olympic Coach, Armas Valste, clarified that the initial contact of the foot should not be made with the heel. Valste stated that the runner who lands on his heel first will cause deceleration and jarring of the body. Running high on the toes causes soreness in the calves of the legs; therefore, the most successful running form includes a foot action which allows for contact with the ground by the

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[1]Wilt, "Modern Distance Running," an unpublished talk before the National Collegiate Track Coaches Association, January 12, 1950.

ball of the foot. The toe should be lifted just prior to ground contact.

According to Thompson,[1] all runners should contact the ground high on the toes. Track shoes with spikes aid the runner in staying up on the toes. Running with high knees enables the runner to obtain maximum power from her legs and thighs.

Dyson[2] reports that the runner's foot action is a natural and instinctive movement. The foot contacts the ground initially on the outside edge with the toes pointing slightly outward. The point at which full body weight is taken on the foot varies with the runner's speed. Sprinters land on the outside of the foot and then the body weight is taken high on the ball of the foot. The distance runner lands on the outside of the foot and full body weight is taken almost flat-footed. Both types of form allow the heel to touch momentarily as the body passes over the foot.

Ancient Greek records, reported on vases, portray the sprinter's running style as being high up on the toes, having well-raised knees, erect bodies, and vigorous arm actions.[3] According to Doherty, sprinting style is a natural, ancient

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[1]Donnis Hazel Thompson, Women's Track and Field (Boston: Allyn and Bacon, Inc., 1969), p. 6.

[2]Geoffrey Dyson, The Mechanics of Athletics (University of London Press LTD, 1967), p. 113.

[3]Kenneth J. Doherty, Modern Track and Field (Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1953), p. 48.

and little-changed art.[1] The author emphasizes the bounce in the sprinter's stride as being dependent upon the amount of relaxation in the ankles. When the runner's toe contacts the ground, the ankle completely relaxes to cushion the landing and permit the foot to drop down.

In distance running (880 and the mile) Doherty states that the runner should land on the ball of the foot. Because of the necessity of economizing effort in the distance runs, the weight drops lightly and buoyantly on the heel with slight settling and relaxing before bouncing back to the ball and toes.

Summary

A review of the literature indicated that the present study did not duplicate any previous investigations. No cinematographic research was discovered with respect to women's toe-heel action during ground contact.

Reviews of pertinent studies and articles involved with foot action were presented in this chapter. A cinematographic study conducted by Nett sought to determine exactly how the foot was planted. The investigator concluded, through analysis of film data of the best German runners, that the action of foot plant was determined by the distance of the race.

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[1]Doherty, Modern Track and Field, p. 169.

Deshon and Nelson undertook a cinematographic analysis to determine the relationship between speed and the following variables: (1) the length of two strides (a cycle); (2) the angle that the leg is raised in front of the body; and (3) the angle of the leg with the ground at touchdown. Nineteen male subjects were filmed while running at maximum speed for fifteen yards. Significant relationships between speed and the variables were discovered at the .05 level except between the mean angle of leg lift and mean angle of leg at touchdown.

Bosen's article was concerned with the amount of heel touch during ground contact. The heel contacts the ground longer in the distance runs than in the sprint runs because of the necessity of economizing effort.

According to Haney, there are certain stride characteristics for each running event. The form in distance running is the most natural of all the running styles because of the initial contact of the heel on the ground. The most obvious differences between middle distance running and sprint running are the sprinter's high pointed knees, lack of back arch, and a pronounced driving action of the arms.

Wilt states that initial ground contact of sprinters should be made on the outer edge of the ball of the foot followed by the heel which touches only momentarily. In agreement with Wilt is Valste, Finland's Olympic Coach. He states that initial contact of the heel causes deceleration and jarring of the body while running high on the toes will result in sore calf muscles. The most successful running form,

therefore, includes contact with the ground made on the ball of the foot.

Doherty and Thompson advocate a running form which enables the runner to remain high on the toes. Characteristically, this form includes high knees, erect bodies, and vigorous arm action. Doherty emphasizes the importance of the sprinter's bounce which is attributed to completely relaxed ankles upon ground contact. Doherty states that the distance runner (880 and the mile) should contact the ground on the ball of the foot. The heel is in contact with the ground for a longer period of time than in the sprint runs because of the importance of economizing effort.

Reporting that the runner's foot action is an instinctive and natural movement, Dyson states that the runner first contacts the ground on the outside of the foot. Sprinters then take the full body weight high on the ball of the foot, whereas the distance runner's body weight is taken almost flat-footed. For both running forms, the heel touches momentarily as the body passes over the foot.

Chapter III presents the methods and procedures which were used in the present study.

CHAPTER III

METHODS AND PROCEDURES

The general purpose of the study was to determine, through cinematography, the toe-heel action during ground contact of women runners competing in national track meets. The specific purpose of the study was to determine the relationship of the toe-heel action during ground contact in the following events: (1) the mile run, (2) the 880 yard run, (3) the 440 yard dash, (4) the 220 yard dash, and (5) the 100 yard dash.

The present chapter consists of the methods and procedures used in the attainment of the purpose of this study. Included are preliminary procedures, selection and description of the subjects, selection and description of instruments, procedures followed in filming the skill, procedures followed in analyzing the skill, and preparation of the final written report.

The data utilized in this study were from both human and documentary sources. The human subjects used in this investigation were seventy-five highly skilled women runners competing in the five selected track events in two national track meets.

Documentary sources included books, periodicals, pamphlets, and bulletins related to the study. Theses, dissertations, and other unpublished materials pertinent to the investigation were used.

Preliminary Procedures

The investigator surveyed and assimilated information related to all aspects of the study. This information was used in the formation of a tentative outline.

Permission to conduct the study was secured from Doctor Anne Schley Duggan, Dean of the College of Health, Physical Education, and Recreation at the Texas Woman's University, Denton, Texas. The investigator also obtained approval for filming from the director of the Third National Women's Intercollegiate Track and Field Championships, Cheney, Washington, and from the director of the Pan-American Trials, Urbana, Illinois.

The outline of the proposed study was developed by the investigator and approved by the members of the thesis committee. On July 2, 1971, the completed tentative outline of the thesis was presented at a Graduate Seminar. In accordance with suggestions offered by those participating, the outline was revised. A prospectus of the approved study was filed in the Office of the Dean of Graduate Studies at the Texas Woman's University.

Selection and Description of the Subjects

The subjects chosen for this study were fifteen women runners who were competing in each of the following events in the Third National Women's Intercollegiate Track and Field Championships, Cheney, Washington, and the Pan-American Trials, Urbana, Illinois: (1) the mile run, (2) the 880 yard run, (3) the 440 yard dash, (4) the 220 yard dash, and (5) the 100 yard dash. A listing of the runners competing in the selected events from the two national meets is presented on pages 47, 48, and 49, in the Appendix.

Selection and Description of Instruments

The following criteria were established for the selection of the camera to be used in the study: (1) a fast shutter speed to alleviate blurring, (2) a large image to provide for a larger and clearer picture of the subjects, and (3) a high camera speed in order to film as much action as possible.

The film data were collected by means of a sixteen millimeter Bell and Howell 70 HR camera. This type of camera produced a larger image and contained greater detail than an eight millimeter camera. The camera was powered by a hand-wound clock-work motor which was wound prior to the filming of each event. The camera contained a forty degree shutter opening or 1/576th of a second exposure which allowed for a sharp frame by frame image of the runner's foot action. A 1.6 wide angle lens was used for the filming because its large viewing area

allowed the investigator to place the camera at an optimum distance from the subjects.

Kodak Black and White Tri-X Reversal Film, perforated on both edges, was used for filming. This high speed film allows for filming under conditions of low level illumination. The camera used in this study, however, provided the proper exposure necessary for outdoor filming. A Sekonic light meter was used to determine the f-stop setting on the camera. From the data collected in the preliminary study, the investigator determined that the proper f-stop reading for the camera's shutter speed was two f-stops down from the reading on the light meter. The f-stop range on this camera was 1.6 to 16. The film was taken at a speed of sixty-four frames per second, which was the fastest speed at which the camera would run.

Procedures Followed in Filming the Skill

The subjects in all five running events were filmed with the camera placed on the ground at a right angle to the runners and nine feet from the track's edge. This distance was selected because the average runner's stride length is from six to seven feet, and the investigator wanted to film as many feet during ground contact as possible. The races were filmed at the following locations: (1) the mile run, at the 1200 and the 1600 yard marks, (2) the 880 yard run, at the 400 and the 800 yard marks, (3) the 440 yard dash, at the 220 yard mark, (4) the 220 yard dash, at the 180 yard mark, and (5) the 100 yard dash, at the 60 yard mark.

The film was developed by Producer's Service, Incorporated in Dallas, Texas.

Procedures Followed in Analyzing the Skill

The films were projected for initial viewing by means of a sixteen millimeter analyzer projector. The film was then viewed frame by frame on the projector in order to collect the data necessary to the study. The film image of the runners' feet was projected onto a piece of plotting paper on the wall while the projector was set at a distance of five feet from and at right angles to the paper. Beginning with the frame of the foot's initial contact with the ground, the investigator plotted the foot frame by frame until that foot left the ground. The plotting consisted of drawing the outline of the runner's shoe while any part of it was in contact with the ground. A diagram of the plottings is presented on pages 44, 45, and 46, in the Appendix.

From the analysis of the plotted data the investigator was able to determine what part of the foot hit first, second, et cetera, until that foot left the ground. Analysis of the two filmings of the 880 yard run and the two filmings of the mile run indicated that there were no variations of foot action during ground contact at two different locations of each race. Apparently, the type of toe-heel contact was consistent throughout each race. The duration of ground contact in all five events was established by the number of frames elapsed. The actual speed of the camera was seventy-two frames per second.

The time (in seconds) of ground contact for each subject was figured by dividing the number of frames of actual ground contact by seventy-two (actual frame per second camera speed).

The investigator was unable to analyze the toe-heel action of all the subjects filmed because of unavoidable circumstances. The curbing on the track's edge at the Third National Women's Intercollegiate Track and Field Championships, Cheney, Washington, blocked the view of the foot action in the first lane. In many instances, one runner's foot blocked the view of another runner's foot.

Preparation of the Final Written Report

Upon completion of the analysis of the data collected, the investigator organized and presented the data in the appropriate tables and illustrations. The data were summarized and conclusions were drawn. A final written report of the study was concluded which contained implications of the findings and recommendations for further studies. A bibliography and appendices were added in order to complete the written report.

Summary

In this chapter, the investigator described the procedures followed in the development of the study under the following headings: preliminary procedures, selection and description of the subjects, selection and description of instruments, procedures followed in filming the skill, procedures followed in analyzing the skill, and preparation of the final written report.

Preliminary procedures consisted of obtaining permission to undertake the study, developing a Tentative Outline and presenting it in a Graduate Seminar at the Texas Woman's University, Denton, Texas, revision of the outline, and filing of the approved outline in the Office of the Dean of Graduate studies in the form of a Prospectus. Permission to do the filming was obtained from the directors of the two national track meets, and permission was secured from the Dean of the College of Health, Physical Education, and Recreation at the Texas Woman's University, Denton, Texas, for the use of the necessary photographic equipment.

The investigator used the process of cinematography because of the application to kinesiological analysis of movement skills which was possible through this type of study. Procedures were developed, decisions were made concerning pertinent details, the subjects were filmed according to established criteria, and the various films were developed by Producer's Service, Incorporated in Dallas, Texas.

The following procedures were adhered to in writing the final written report of the study: (1) preparation, presentation, approval, and submission of the outline for filing with the Dean of Graduate Studies; (2) development of each chapter with revisions by the members of the thesis committee incorporated into each chapter; (3) report of the findings in tabular form; (4) preparation of a written report of the study including conclusions drawn and recommendations for further

studies; (5) preparation of a bibliography; and (6) preparation of the appendices.

In Chapter IV of this thesis, the investigator will present the findings of the study.

CHAPTER IV

ANALYSIS OF DATA AND RESULTS

Introduction

In Chapter IV the results of the film analysis are presented in narrative and tabular form. The purpose of the present investigation was to determine the relationship between running speed and toe-heel action during ground contact of highly skilled women runners. The study entailed the analysis of film records of fifteen runners competing in each of the following: (1) the mile run, (2) the 880 yard run, (3) the 440 yard dash, (4) the 220 yard dash, and (5) the 100 yard dash.

The film data were collected at the two national track meets, The Third National Women's Intercollegiate Track and Field Championships, Cheney, Washington, and The Pan-American Trials, Urbana, Illinois, by means of a sixteen millimeter Bell and Howell 70HR camera. The camera was stationed on the ground nine feet from the track's edge and was positioned at the following locations: (1) for the mile run, at the 1200 and the 1600 yard marks, (2) for the 880 yard run, at the 400 and the 800 yard marks, (3) for the 440 yard dash, at the 220 yard mark, (4) for the 220 yard dash, at the 180 yard mark, and (5) for the 100 yard dash, at the sixty yard mark.

The film was viewed frame by frame through a sixteen millimeter analyzer projector. Plottings of each runner's foot were made beginning with initial contact with the ground and ending when that foot left the ground. Analysis of the data provided the information as to which part of the foot hit first, second, et cetera, and how the foot left the ground.

Presentation of the Data

Table 1, presented on this page, illustrates the type of initial contact of women runners competing in the five running events. Each event will be discussed in the following paragraphs.

TABLE 1

TYPE AND FREQUENCY OF INITIAL GROUND CONTACT

Distance	Ball of foot	Flat-footed	Heel of foot	Total
100 yard dash	13	2		15
220 yard dash	13	2		15
440 yard dash	7	8		15
880 yard run	3	2	10	15
mile run	1	1	13	15
Total runners 75				

As indicated by Table 1, of the fifteen runners who competed in the 100 yard dash, thirteen (86.6 per cent) established

initial ground contact on the ball of the foot. Two (13.3 per cent) of the runners contacted the ground with a flat foot.

Table 1 also reveals the type of initial contact made by the runners in the 220 yard dash. Thirteen (86.6 per cent) of the fifteen runners initially contacted the ground on the ball of the foot. Two (13.3 per cent) established initial contact with a flat foot.

Also illustrated in Table 1 is the type of initial contact of the runners competing in the 440 yard dash. Out of a total of fifteen runners analyzed, seven (46.6 per cent) contacted the ground with the ball of the foot, whereas eight (53.3 per cent) established ground contact with a flat foot.

Table 1 further depicts the data for initial contact during the 880 yard run. Three (20 per cent) of the fifteen runners contacted the ground on the ball of the foot, two (13.3 per cent) established contact with a flat foot, and ten (66.6 per cent) contacted on the heel.

As revealed by the data presented in Table 1, a majority of thirteen (86.6 per cent) of the fifteen runners in the mile run established initial ground contact with the heel of the foot. One (6.6 per cent) contacted the ground with the ball of the foot, and one (6.6 per cent) contacted flat-footed.

Table 2, presented on page 32, indicates the number of frames and time, in seconds, of ground contact time for each of the five running events. The time, in seconds, is based upon the camera speed which was seventy-two frames per

second. Contact time for the fifteen runners competing in the 100 yard dash was between eight and ten frames or .111 to .138th of a second, respectively. Those runners competing in the 220 yard dash established contact for the same number of frames as did the runners in the 100 yard dash. The fifteen subjects in the 440 yard dash, however, contacted the ground from ten to twelve frames, or .138 to .167th of a second, respectively. Ground contact was established by the fifteen runners who competed in the 880 yard run between twelve and fifteen frames, or .167 to .208th of a second, respectively. Those fifteen subjects who competed in the mile run established ground contact in fifteen to seventeen frames, or .208 to .236th of a second, respectively.

TABLE 2

NUMBER OF FRAMES AND TIME OF GROUND CONTACT

No. of Subjects	Distance	No. of frames	Time (in secs.)
15	100 yd. dash	8-10	.111-.138
15	200 yd. dash	8-10	.111-.138
15	440 yd. run	10-12	.138-.167
15	880 yd. run	12-15	.167-.208
15	mile run	15-17	.208-.236
Total 75			

As illustrated on page 44, in the appendix, the type of initial contact with the ground did not affect the foot plant or action in the succeeding frames. Regardless of the distance of the race, those runners who initially contacted the ground on the ball of the foot went to a flat foot (within one to two frames), to the ball of the foot, and left the ground from the toe. Those runners who established initial contact on the heel of the foot immediately went to a flat foot position (within one to two frames), to the ball of the foot, and left the ground from the toe. The subjects who initially contacted the ground with a flat foot travelled to the ball of foot, and left the ground off the toe.

Summary

Film records were collected on fifteen highly skilled women runners who competed in the following events: (1) the mile run, (2) the 880 yard run, (3) the 440 yard dash, (4) the 220 yard dash, and (5) the 100 yard dash. Frame by frame plottings were made of each runner's foot beginning with initial ground contact and continuing until that foot left the ground. Analysis of the film data was presented in narrative and tabular form.

Table 1, presented on page 30, illustrated the type of initial ground contact in the five running events. A majority of the runners in the 100 (86.6 per cent) and the 220 yard (86.6 per cent) dashes established contact with the ground on the ball of the foot. Initial contact in the 440 yard run

was executed with a flat foot by a majority (53.3 per cent) of the fifteen runners. In the longer runs, the 880 and the mile, a majority of the runners, 66.6 per cent and 86.6 per cent, respectively, made contact with the heel.

Duration of ground contact was presented in Table 2 on page 32. Those runners competing in the 100 and in the 220 yard dashes maintained contact with the ground ranging from eight to ten frames, or .111 to .138th of a second, respectively. The range of duration of ground contact in the 440 yard run was from ten to twelve frames, or .138 to .167th of a second. Those runners in the 880 yard run established contact with the ground between twelve and fifteen frames, or .167 to .208th of a second, respectively. Ground contact in the mile run was maintained by the runners between fifteen and seventeen frames, or .208 to .236th of a second.

An example of the plottings of the foot action during ground contact is presented in the appendix, pages 44-46, in order to illustrate that the action of the foot from the second or third frame on is the same for all runners regardless of the distance. Those runners who land on the ball of the foot proceed to a flat foot, to the ball of the foot, and finally leave the ground off the toe. Those runners who land on the heel proceed (within one to two frames) to the flat foot position, to the ball of the foot, and off the ground from the toe. Those runners who initially contact the ground with a flat foot proceed to the ball of the foot and leave the ground off the toe.

Chapter V contains a discussion of the results relative to the purposes of this study, and conclusions and recommendations for future studies.

CHAPTER V

SUMMARY, FINDINGS, CONCLUSION, AND RECOMMENDATIONS

Introduction

The present chapter is a review of the study with the purposes presented and discussed. A conclusion to the study is drawn, and recommendations for future studies are suggested.

Summary

Few studies have been conducted with respect to the runner's toe-heel action during ground contact. There has been one cinematographical investigation concerned with the foot action during ground contact, but no such studies have been conducted concerning women runners.

The purpose of the present investigation was to determine, through cinematography, the toe-heel action during ground contact of women runners competing in national track meets. Specifically, the investigator sought to determine the relationship between toe-heel action and the following five events: (1) the mile run, (2) the 880 yard run, (3) the 440 yard dash, (4) the 220 yard dash, and (5) the 100 yard dash.

Evidence of conflicting theories is reported in the related literature concerning toe-heel action during ground contact. Wilt, Valste, Doherty, Thompson, and Bosen all

advocate that initial contact should be made with the ball of the foot in all running events. They also state that the heel will always contact the ground regardless of the distance of the race. Doherty and Bosen state that the heel is in contact with the ground for a longer period of time in the distance runs than in the sprint runs because of the necessity of economizing effort.

Haney is one of the few authorities who advocates that initial contact should be established on the heel for all distance runs. He states that the extensor muscles are not taxed as heavily when the heel touches first than when the toe contacts first; thus, the runner is able to run for a longer period of time.

Two cinematographic studies which were pertinent to the present investigation were conducted by Nett and by Deshon and Nelson. Nett undertook a study of the best German runners in order to determine exactly how the foot was planted during ground contact and to ascertain if there was any relationship between foot plant and the distance of the race. The races, which ranged from the 100 meter event to the marathon event, were filmed at sixty-four frames per second. Nett concluded that the method of foot plant was determined by the distance of the race and that runners at all distances plant the foot on the outside edge. He also concluded that at all distances beyond 1500 meters, initial contact is made on the outside edge of the foot between the heel and the metatarsus. Deshon and Nelson concluded, through cinematographic analysis, that

a significant relationship existed at the .05 level between speed and the length of two strides.

In the present study the film data were collected, by means of a sixteen millimeter Bell and Howell 70HR camera, on fifteen runners competing in each of the five events. The camera was stationed on and parallel to the ground at a right angle to the runners. The filming occurred nine feet from the track's edge at the following locations: (1) for the mile run, at the 1200 and the 1600 yard marks, (2) for the 880 yard run, at the 400 and the 800 yard marks, (3) for the 440 yard dash, at the 220 yard mark, (4) for the 220 yard dash, at the 180 yard mark, and (5) for the 100 yard dash, at the sixty yard mark. Analysis of the data collected from the two filmings of the 880 yard run and the mile run revealed that the type of toe-heel contact executed was consistent at the two distances filmed.

The films, collected at the Third National Women's Intercollegiate Track and Field Championships, Cheney, Washington, and The Pan-American Trials, Urbana, Illinois, were viewed by means of a sixteen millimeter analyzer projector. Frame by frame plottings (outline of the runner's shoe) were made of each runner's foot beginning with the frame of initial contact and continuing until that foot left the ground.

Findings of the Study

The following findings were based upon the data obtained from the present study:

1. Initial contact in the 100 yard dash was established on the ball of the foot by a majority of thirteen (86.6 per cent) of the fifteen runners.

2. Initial contact in the 220 yard dash was established on the ball of the foot by a majority of thirteen (86.6 per cent) of the fifteen runners.

3. Initial contact in the 440 yard dash was established with a flat foot by a majority of eight (53.3 per cent) of the fifteen runners.

4. Initial contact in the 880 yard run was established on the heel by a majority of ten (66.6 per cent) of the fifteen runners.

5. Initial contact in the mile run was established on the heel by a majority of thirteen (86.6 per cent) of the fifteen runners.

6. Duration of ground contact for those runners in the 100 yard dash ranged from eight to ten frames, or .111 to .138th of a second.

7. Duration of ground contact for those runners in the 220 yard dash ranged from eight to ten frames, or .111 to .138th of a second.

8. Duration of ground contact for those runners in the 440 yard dash ranged from ten to twelve frames, or .138 to .167th of a second.

9. Duration of ground contact for those runners in the 880 yard run ranged from twelve to fifteen frames, or .167 to .208th of a second.

10. Duration of ground contact for those runners in the mile run ranged from fifteen to seventeen frames, or .208 to .236th of a second.

11. Irregardless of the distance of the race, and after initial ground contact, all subjects involved pushed off or followed through from a flat foot to the ball of the foot, and they left the ground off the toe of the foot.

Conclusion

The primary purpose of the study was to determine the relationship between toe-heel action during ground contact and running speed. The investigator concluded that a definite relationship exists between running speed and toe-heel action of highly skilled women runners. During short sprints (100 and the 220 yard dashes) most runners contact the ground on the ball of the foot. As the distance of the race increases the runner's pace decreases, and he initially contacts the ground farther back on the foot. Initial contact in the 440 yard dash was established by most runners on a flat foot, whereas in both the 880 and the mile run initial contact was established by most runners on the heel of the foot. Duration of ground contact is directly proportional to the distance of the race. As the distance increases the time of ground contact also increases.

Recommendations for Future Studies

The following recommendations are suggested for additional investigations:

1. Conduct a study similar to determine the extent of pronation-supination of the foot during ground contact of women runners.

2. Conduct a study to investigate the angle of shin (leg) at moment of contact and its relation to foot plant.

3. Conduct a study similar to the present one but use a faster camera speed than sixty-four frames per second.

4. Investigate the relationship of stride length to foot plant.

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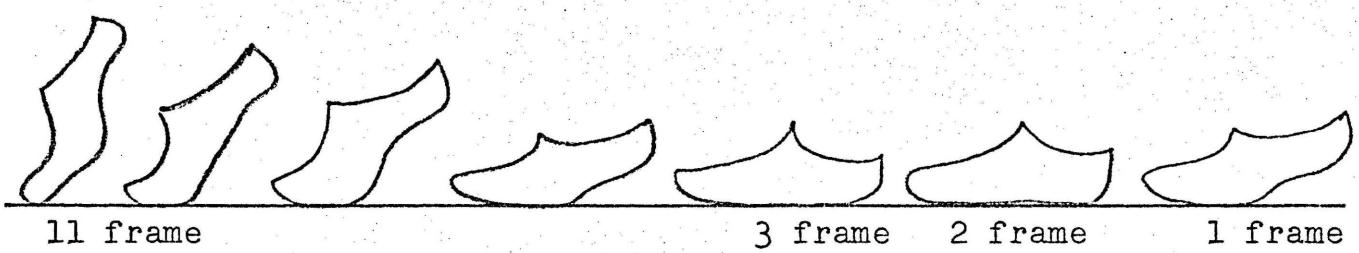
APPENDIX

APPENDIX A

TOE-HEEL ACTION DURING GROUND CONTACT WITH INITIAL BALL CONTACT

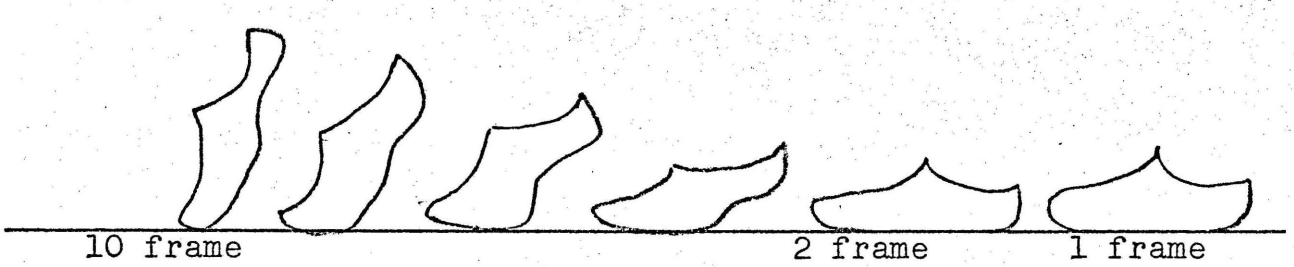


FREQUENCY OF INITIAL BALL CONTACT

Distance	Initial Ball Contact	Total No. of Subjects
100 yd. dash	13	15
220 yd. dash	13	15
440 yd. dash	7	15
880 yd. run	3	15
mile run	1	15

APPENDIX B

TOE-HEEL ACTION DURING GROUND CONTACT WITH INITIAL FLAT FOOT CONTACT



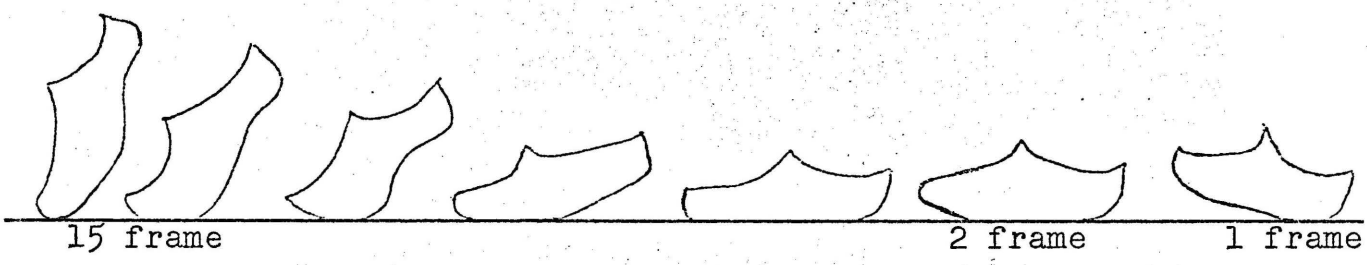
FREQUENCY OF INITIAL FLAT FOOT CONTACT

Distance	Initial Flat Foot Contact	Total No. of Subjects
100 yd. dash	2	15
220 yd. dash	2	15
440 yd. dash	8	15
880 yd. run	2	15
mile run	1	15

APPENDIX C

TOE-HEEL ACTION DURING GROUND CONTACT

WITH INITIAL HEEL CONTACT



FREQUENCY OF INITIAL HEEL CONTACT

Distance	Initial Heel Contact	Total No. of Subjects
100 yd. dash	0	15
220 yd. dash	0	15
440 yd. dash	0	15
880 yd. run	10	15
mile run	13	15

APPENDIX D

PAN-AMERICAN TRIALS, URBANA, ILLINOIS

100 Yard Dash Finals

Iris Davis (Tennessee State)
Pam Greene (Denver All Stars)
Pat Hawkins (Atoms)
Orien Brown (Texas Southern)
Mattline Render (Tennessee State)
Mildred Netter (Alcorn)
Mable Ferguson (West Coast)
Judy Murphy (Texas Woman's University)

220 Yard Dash Finals

Pam Greene (Denver All Stars)
Robyn Russell (Cleveland Recreation)
Kathy Lawson (Liberty Athletic Club)
Patrice Benson (Denver All Stars)
Esther Stroy (Sports International)
Mable Fergerson (West Coast Jets)
Laurie Barr (Ohio Track Club)
Jill Thomas (Kirkwood Track Club)

440 Yard Dash Finals

Mavis Laing (Phoenix Track Club)
Gwen Norman (Sports International)
Gail Fitzgerald (Atoms)
Jane Burnett (Sports International)
Jarvis Scott (Los Angelos)
Esther Stroy (Sports International)
Lissa Natkin (Sports International)
Sue Dudley (Wolverines)

880 Yard Run Finals

Cheryl Toussaint (Atoms)
Doris Brown (Falcon Track Club)
Cis Schafer (Millbrae Lions)
Ann Gallaher (Phoenix Track Club)
Terry Crawford (Knoxville Track Club)
Carol Hudson (Albuquerque Olympette)
Shelly Marshall (Atoms Track Club)
Francea Johnson (Liberty Athletic Club)

APPENDIX E

THIRD NATIONAL WOMEN'S INTERCOLLEGIATE TRACK AND FIELD CHAMPIONSHIPS, CHENEY, WASHINGTON

100 Yard Dash Semi-Finals

Chi Cheng (CSPC - Pomona)
Judy Murphy (Texas Woman's University)
Kathy Smallwood (CSPC - Pomona)
Wanda Taylor (U. of Oregon)
Lisa Chiavario (U. of New Mexico)
Rochelle Barker (Texas Woman's University)
Vicki Vernon (West Texas State)
Vivian Hughes (CSPC - Pomona)
Sue Lyons (CWSC)
Jeri Nored (Oregon State)
Joan Zimmerer (Texas Woman's University)
Alma Gapsch (CWSC)
Pat Lopez (CSPC - Pomona)
Roberta Stetson (FVCC)
Peggy Robinson (Ore. State)
Peggy Sandeen (Oregon State)
Linda Ingram (Southern Oregon)
Julie Jensen (WWSC)
Shelly Callium (Cal. St. - Hayward)

220 Yard Dash Semi-Finals

Kathy Smallwood (CSPC - Pomona)
Judy Murphy (Texas Woman's University)
Wanda Taylor (U. of Oregon)
Cheron Billeck (Texas Woman's University)
Susan Bronson (FVCC)
Sylvia Longoria (Texas Woman's University)
Vivian Hughes (CSPC - Pomona)
Dee Stoneback (EWSC)
Linda Rowe (Graceland)
Mary Scott (CWSC)
Geannette Smith (Seattle-Pacific)
Gerrie Brockman (West Texas)
Sue Longsford (Oregon State)
Barb Talley (Portland State)
Stephanie Sceva (Oregon State)
Alma Gapsch (CWSC)
Cheryl Blaine (Oregon State)
Pam Peterson (Portland State)

440 Yard Dash Semi-Finals

Cis Shafer (Cal. St. - Hayward)
Shirley Swanson (WWSC)
Sylvia Longoria (Texas Woman's University)
Marion Service (U. of Washington)
Mary Rae Evans (Oregon State)
Gerrie Brockman (West Texas State)
Chris Moore (U. of Oregon)
Barbara Eastep (Texas Woman's University)
Sandy Needham (Portland State)
Gloria Martin (Oregon State)

880 Yard Run Semi-Finals

Cis Shafer (Cal. St. - Hayward)
Sherry Wells (U. of Oregon)
Carolyn Kruckeburg (CWSC)
Cindy Arbelbide (Oregon State)
Rosie Orta (Texas Woman's University)
Diane Hooker (Texas Woman's University)
Sharon Burgess (Florida State)
Judy Smith (West. New Mexico)
Virginia Brown (FVCC)
Linda McArthur (CSPC - San Luis Obispo)
Gayle Fenner (FVCC)
Leslie Stockton (CWSC)
Charise Clardy (CSPC - Pomona)
Angie Williams (CSPC - Pomona)

Mile Run Semi-Finals

Caroline Kruckeburg (CWSC)
Linda McCain (Cal. St. - Hayward)
Judy Smith (West. New Mexico)
Sharon Burgess (Florida State)
Rosie Orta (Texas Woman's University)
Janet Freedenbrug (Southern Oregon)
Caylene Caddell (Texas Tech)
Kay Carter (Oregon State)
Gayle Fenner (FVCC)
Diane Hooker (Texas Woman's University)
Debbie Johnson (Oregon Coll. Ed.)
Connie McArthur (U. of Washington)
Leslie Stockton (CWSC)
Angie Williams (CSPC - Pomona)