8-14-1967

A Cinematographical Analysis Of The Mechanical Differences Between Running On A Motor-Driven Threadmill And A Stationary Surface.

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This thesis, directed and approved by the candidate's committee, has been accepted by the Graduate Committee of the University of New Mexico in partial fulfillment of the requirements for the degree of

MASTER
OF
SCIENCE

Art Sleeper
Dean

Date 8-14-67

A CINEMATOGRAPHICAL ANALYSIS OF THE MECHANICAL DIFFERENCES BETWEEN RUNNING ON A MOTOR-DRIVEN TREADMILL AND A STATIONARY SURFACE

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B.S., Eastern New Mexico University, 1966

THESIS

Submitted in Partial Fulfillment of the
Requirements for the Degree of
Master of Science
in the Graduate School of
The University of New Mexico
Albuquerque, New Mexico
July, 1967

ACKNOWLEDGEMENTS

The writer wishes to express deep appreciation to Drs. Lloyd Burley and William Bynum for their extraordinary criticism, advice, and encouragement given throughout this study. This study is dedicated to my wife Dee who made it possible.

ABSTRACT

It was the purpose of this study to determine, through a cinematographical analysis, if running on a treadmill produced a change in running style or form by comparing eleven measurements including body lean, various angles of the extremities, length of stride, and vertical body movement.

An investigation of the literature revealed that little had been done to analyze the true mechanics of running on a treadmill. There has been a large amount of research and experimentation using treadmills in universities and industry to produce a controlled situation for physiological and kinesiological studies.

The major research method used in conducting this study was cinematography, the recording of external body movement upon motion-picture film.

The subjects chosen were individuals who ran either sprints or distances on the University of New Mexico track team. The main objective of the study was to have each runner filmed running comfortably at 8.168 miles per hour on the treadmill and on a stationary surface. The two film strips of each runner were then analyzed in comparison to each other. The filming was done with control of the following variables: speed of runner, camera placement, projector placement, and projection techniques.

The frames were projected onto a grid screen, and moving through each runner's film strip, measurements were taken at optimum points.

Both groups underwent an analysis of variance to determine if enough differences existed to achieve the criterion of 5 per cent level of confidence.

The results of the analysis of variance indicates that there were no statistically significant differences between running on the motor-driven treadmill and the stationary surface as measured by the eleven measurements.

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CHAPTER I

INTRODUCTION

Hubbard[1] stated that running has been an integral part of many sports in which man participates, but there are some differences in the form and style of running for various activities. However, Cureton[2] stated that fast sprint running or slow endurance running were essentially the same for all sports and activities.

Running has been studied in many different ways. In recording work and endurance, the treadmill has been used extensively. There are many and varied patterns to running, so only general principles are applicable here. The stride of the runner, the period of float, the push-off, the proper body posture, and the knee and arm lift are very important parts of an integrated whole. These must be analyzed mechanically and understood by both coaches and researchers.

When coaches and physical educators watch a group of boys running, there are usually one or two important factors with which they are concerned. Who are the fastest and/or

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[1] American Association for Health, Physical Education, and Recreation, Research Methods in Health, Physical Education and Recreation (Washington: American Association for Health, Physical Education, and Recreation, 1959), p. 338.

[2] T. K. Cureton, "Elementary Principles and Techniques of Cinematographical Analysis as Aids in Athletic Research," The Research Quarterly, 10:3-24, May, 1939.

how fast the race was run in terms of time and distance. It is suspect whether much thought was given to what mechanical factors were different between the slow and fast runner. This statement may be untrue of many coaches of track, but for the many thousands of other persons who are involved with people running, the statement seems justified. This should not be the situation in an activity of such universal importance to those in the fields of athletic coaching and physical education.

The increasing use of treadmill running for research purposes has brought about the need to understand the implications of running and training on a treadmill to determine if this produces or encourages a change in normal running form and style.

I. THE PROBLEM

Statement of the problem. It was the purpose of this study to evaluate, through a cinematographical analysis, if running on a treadmill produced a change in running style or form by comparing body lean, various angles of the extremities, length of stride, and vertical body movement.

Scope of the problem. The University of New Mexico Human Performance Laboratory is engaged in studying various physiological, fitness, and altitude problems. The treadmill has been used extensively in these studies. Varsity athletes

have been used in many of the tests, and the possible differences in style or form caused by the mechanics of the treadmill itself have been questioned.

An investigation of the literature revealed that little had been done to analyze the true mechanics of running on a treadmill. There has been a large volume of research and experimentation using treadmills in universities and industry. Treadmills have been used to produce a controlled situation for running to record physiological, kinesiological, and various other measurements. The researchers appear to have assumed that the treadmill produced the same mechanics as running. This assumption could be damaging to many studies because, if work cost differences do exist mechanically, they might also exist physiologically and otherwise.

Hypothesis. A cinematographical study of a group of individuals running on a motor-driven treadmill and on a stationary surface will reveal no significant mechanical differences in performance.

II. DEFINITIONS OF TERMS USED

Center of gravity. The center of gravity is the theoretical center of the concentration of the mass. It is the reference point which may be used to represent the body mass as a whole as it acts in various physical formulae.

Cinematography. The act or science of motion-picture photography.

Cycle. The distance covered, in feet and inches, by two strides of the runner. This begins when one foot leaves the ground and ends when it leaves the ground a second time..

Mechanics. The branch of physics that deals with motion and the phenomena of the action of forces on bodies.

Motor-driven treadmill. A motor-driven treadmill is an endless belt wrapped around two drums. The belt was a nineteen-foot standard A. R. Young model with a sixty-three-inch running surface and a twenty-four-inch width.

Pacer. A pacemaker that sets a certain speed that others try to equal, as in a race.

Period of float. That period in the stride when neither foot is in contact with the running surface.

Period of support. That period in the stride when one of the feet is in contact with the running surface.

Point of touchdown. That point where the foot first touches the ground in the forward stride.

Stationary run. The sequence filmed on the flat, stationary surface of the University of New Mexico Varsity Track.

Style or form. "Style" is the way a runner swings his arms, holds his body, or moves his legs; it is the individual way of performing.

III. SUMMARY

This chapter introduced the topic, stated the problem, presented an hypothesis, and defined terms.

CHAPTER II

REVIEW OF LITERATURE

A number of experimental studies have been made analyzing an athletic skill by the means of cinematography. Cureton[3] stated that external mechanical acts of skill can be analyzed in a rather precise manner by means of motion-picture analysis. "The fundamental principle is that directions of movement (angles), dimensions, time relations, and indirect values of force and velocity may all be obtained from the projected film. The science of mechanics is an expression of physical laws of equilibrium or movement and a mechanical analysis of any movement may be made from measurements taken from the screen."

He further stated that these measurements made through the technique of cinematography used frame analysis to study scientifically and correctly the physical performance of an individual.

I. HISTORY

The word cinematograph was first used by Bouly[4] in 1892

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[3] _Ibid_., p. 5.

[4] G. Bouly, French Patent No. 219,350, February 12, 1892, cited by A. R. Michaelis, _Research Films in Biology, Anthropology, Psychology, and Medicine_ (New York: Academic Press, Inc., 1959), pp. 1-3.

while applying for a French patent specification for a camera. It has been generally accepted that cinematography was not invented by a single person and that no particular country can claim its birthright. The gradual development of the projector preceded that of the camera by centuries. The development of cinematographic recording techniques was done in large part by E. Muybridge[5] and E. J. Marey.[6] The final synthesis of camera and projector by W. Friese-Green[7] has allowed the rise to the present level of cinematography.

In 1872 Eadweard Muybridge[8] used cinematography to find the nature of paces of running horses. Kohlrausch[9] and others started making extensive applications of physics to the human

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[5] E. Muybridge, "The Attitudes of Animals in Motion," Proc. Roy. Instn., G. B., 1882, X, 44 (March 13), cited by T. K. Cureton, "Elementary Principles and Techniques of Cinematographical Analysis as Aids in Athletic Research," The Research Quarterly, 10:3-24, May, 1939.

[6] E. J. Marey, La Photographie du Mouvement (Paris: Carre, 1892), cited by A. R. Michaelis, Research Films in Biology, Anthropology, Psychology, and Medicine (New York: Academic Press, Inc., 1959), p. 3.

[7] W. Friese-Green, British Patent No. 10,131, June 21, 1889, cited by A. R. Michaelis, Research Films in Biology, Anthropology, Psychology, and Medicine (New York: Academic Press, Inc., 1959), p. 3.

[8] Muybridge, op. cit., p. 3.

[9] E. Kohlrausch, "Physik des Turnens," Lion, 1887 (contained in the Harvard Library), cited by T. K. Cureton, "Elementary Principles and Techniques of Cinematographical Analysis as Aids in Athletic Research," The Research Quarterly, 10:3-24, May, 1939.

body performing various movements about 1887. In 1892 Marey[10] published a booklet, La Photographie du Mouvement, and shortly afterward Georges Demeny[11] used the photographic method and published a book, Les Bases Scientifique de L'Education Physique. These were the first publications to describe methodology and techniques of cinematography.

Marey's[12] books were the basis of cinematography as he published descriptions of his equipment, demonstrations of high-speed cinematography at sixty frames per second, and the first use of frame analysis.

Michaelis[13] described the basic principle of cinematography as follows: a series of separate images, recorded on the same continuous light-sensitive ribbon and exposed at standard intervals of time, to represent successive phases of movement; when exhibited in rapid sequence above the fusion

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[10]Marey, op. cit., p. 3.

[11]Georges Demeny, Les Bases Scientifique de L'Education Physique, 215-297 (Paris: Felix Alcan, 1903), cited by T. K. Cureton, "Elementary Principles and Techniques of Cinematographical Analysis as Aids in Athletic Research," The Research Quarterly, 10:3-24, May, 1939.

[12]E. J. Marey, La Photographie du Mouvement, (Paris: Carre, 1882); Paris Photographe, 1891, I, 12; Le Mouvement, G. Masson, Paris; Movement, W. Herneman, London, 1895, cited by A. R. Michaelis, Research Films in Biology, Anthropology, Psychology, and Medicine (New York: Academic Press, Inc., 1959), p. 3.

[13]Anthony R. Michaelis, Research Films in Biology, Anthropology, Psychology, and Medicine (New York: Academic Press, Inc., 1959), p. 1.

frequency of human vision, the separate images persist long enough in the mind of the observer to reproduce the appearance of continuous motion.

According to Michaelis,[14] there are many advantages to cinematography. Among them are: (1) permanency of record, (2) continued use of film and ability to see something repeatedly, (3) scope and complexity of the event, (4) span of time and velocity, (5) time sampling, (6) greater range of sensitivity of the photographic emulsion, and (7) quantitative evaluation or frame analysis. A few of the limitations are: (1) subjectivity of camera angle, (2) lack of immediacy, and (3) time and trouble involved.

II. EQUIPMENT

The 35 mm. camera was recommended until recently by Cureton[15] because it was larger, showed detail more clearly, and could be easily enlarged for better reproductions. The 16 mm. has been improved recently, and most researchers have been found to accept it as comparable for quality research. A good camera, variable speed, ordinary and telephoto lenses, a locking tripod, and an editing outfit are bare essentials.

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[14] *Ibid.*, p. 9.

[15] T. K. Cureton, "Elementary Principles and Techniques of Cinematographical Analysis as Aids in Athletic Research," *The Research Quarterly*, p. 5.

Hubbard[16] and Cureton recommended that negative film not be used for measuring projected images, and if negative film is used, it should be inspected for quality and a positive print made. A microfilm reader was found to be excellent for frame-to-frame measurements.

In 1949 Offenhauser[17] recommended that a camera with an 180-degree shutter and a short movement time would provide a sharper picture than the same camera with a 240-degree shutter. In 1959 Hubbard[18] alleged that a shutter with an opening of forty degrees is superior to the normal 160 degrees because it reduces the fuzziness of rapidly moving parts by one-fourth. Valid measurements of movement depend on accurate recording of spatial and temporal relations.[19] The limitations in cinematography are not obvious, and photographic material may appear very realistic yet give no valid basis for measurement. The photographer must arrange to record comparable distances at uniform intervals in standard units of measurement, or the analysis of human movement is restricted.

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[16] Alfred W. Hubbard, "Photography," Research Methods in Health, Physical Education, and Recreation (Washington, D. C.: American Association of Health, Physical Education, and Recreation, 1959), p. 135; T. K. Cureton, "Elementary Principles and Techniques of Cinematographical Analysis as Aids in Athletic Research," The Research Quarterly, p. 6.

[17] William H. Offenhauser, 16-mm. Sound Motion Pictures (New York: Interscience Publishers, Inc., 1949), p. 158.

[18] Alfred W. Hubbard, "Photography," Research Methods in Health, Physical Education, and Recreation, p. 138.

[19] Ibid., p. 132.

III. PROBLEMS

Michaelis[20] proposed that the basic requirements for planning the research film were: (1) a precise knowledge of what was to be filmed, when, and where; (2) detailed planning beforehand; (3) what frequency to be employed, type of camera, location, and support; (4) the correct choice of lens and a scale of length or grid in the field; (5) the correct lighting of the subject, using silver reflectors if in open sunlight and normal photoflood lamps for inside; and (6) a work print or duplicate copy, not the original, should be used for analysis. He further asserts that these requirements suggest a few problems that must be taken care of or accounted for.[21] Spatial relations or perspective errors are caused by some parts of the subject being at a different distance perpendicularly from the camera than others. The camera reduces three-dimensional space to two dimensions, and any appreciable movement or displacement in the third (to-from) dimension is enlarged or diminished. The major movement plane must be determined and the camera set at the center of and perpendicular to this plane. Directly comparable measurements can be made only from pictures taken perpendicular to the plane and at a fixed distance. Some scaled object should be included in the field to allow

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[20] Michaelis, _op. cit._, p. 13.

[21] _Ibid._, p. 15.

for some variation in distance between camera and subject and projector and projection.

Cureton[22] contended that errors of measurement were almost negligible in work with stable objects but were greatly magnified when the camera was very close to the object. A possible means of minimizing this error was to use a telephoto lens and place the camera farther away.

Hubbard[23] maintained that another important error could be made in timing or measuring speed and force. Slow motion pictures aided observation but presented the problem of the interval between frames and the frames per second; i.e., timing the exposure. Cureton[24] agreed that most cameras were not equipped properly to handle this problem, so the photographing of a falling object by a scale, or including a timing device in aberrations, resulted from: (1) astigmatic distortion or uneven curvature of the lens; (2) chromatic aberration or bad dispersing properties in the glass; and (3) spherical aberration or unequal refraction of the light rays. These were all errors or faults in equipment and had to be discovered

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[22] T. K. Cureton, "Elementary Principles and Techniques of Cinematographical Analysis as Aids in Athletic Research," The Research Quarterly, p. 17.

[23] Alfred W. Hubbard, "Photography," Research Methods in Health, Physical Education, and Recreation, p. 133.

[24] T. K. Cureton, "Elementary Principles and Techniques of Cinematographical Analysis as Aids in Athletic Research," The Research Quarterly, p. 18.

through pre-testing and experience.

Frames per second--speed. Offenhauser[25] says that there are many shots for which an exactly standardized speed is not required. Spring-driven cameras are not as accurate as electrically-powered cameras. If a shot is short and if there is no need for synchronization of sound, spring-driven cameras are considered quite satisfactory. Michaelis[26] asserted that high-speed cinematography is among the special cinematographic techniques for specific research projects. It should be employed when rapid human movements are to be analyzed. In field work, a frequency of sixty-four frames per second is usually found to be adequate. In the psychological research laboratory, however, higher camera frequencies often are required. For example, in an analysis of reaction times, Landis and Hunt[27] employed 1,500 frames per second to investigate startle reactions following a pistol shot. Harrison[28] concluded, "That the cinematographic record, when properly made,

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[25] Offenhauser, op. cit., p. 148.

[26] Michaelis, op. cit., p. 183.

[27] C. Landis and W. A. Hunt, "Magnification of Time as a Research Technique in the Study of Behavior," Science, p. 85, 1937.

[28] Francis P. Harrison, "The Contributions 16-MM. Cinematographic Techniques Make to Coaching Football" (unpublished Doctoral dissertation, The University of Michigan, Ann Arbor, 1954), p. 10.

provides more and superior data than that available from observation. By arresting action too rapid for inspection and holding it for prolonged contemplation, the cinematographic record provides facts on which to base a program and transport it from the subjective to the objective."

Gesell[29] set forth that cinematography is made possible by these five fundamental features of technique:

"1. The film propelled at a known speed minutely records values and sequences.
2. Simultaneously and minutely the film records space relationships and configurations.
3. The film records these spatial and temporal data in a series of discrete, instantaneous registrations.
4. These registrations can be serially reinstated at normal, retarded, and accelerated rates.
5. Any single registration can be individually studied, in terms of time and space, as a delineation of a single phase of a behavior pattern or a behavior event."

Lighting. Michaelis[30] maintained that good techniques in specific cases are best learned from the manufacturer's instruction booklet and from a few trials. In actuality,

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[29] A. L. Gesell, "Cinemanalysis: A Method of Behavior Study," Pedagogical Seminary and Journal of Genetic Psychology, 47:3-16, 1935.

[30] Michaelis, op. cit., p. 13.

perfection was acquired only after many trials and much experience. Michaelis lists a number of excellent texts available from which elementary techniques could be learned.

Arnold[31] recommended the use of reflectors outdoors to hold down hard shadow on the subject.

Ehrhart[32] proposed that motion pictures have proven to be a tremendous help in scientific analysis of the techniques employed by athletes in all phases of sports, as well as an adequate means of demonstrating the mechanical principles involved in athletic competition. The direction of movement, related body movement, distance, speed, force, and conditions of equilibrium could be determined directly or indirectly by means of the analysis of motion pictures. Certain basic principles, however, must be followed in order to obtain accurate results from a cinematographic analysis of an activity.

Cinematographical studies have been made in track by Fenn,[33] Deshon, Footrick, Knight and Hepp, Lapp, and Cureton.

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[31] John Arnold, A.S.C., "Cinematography, Professional," The Encyclopedia of Photography (New York: Greystone Press, 1943), p. 91.

[32] Robert Ronald Ehrhart, "A Cinematographic Analysis of the One Mile Run" (unpublished Master's thesis, University of Illinois, Urbana, Illinois, 1957), p. 14.

[33] Wallace O. Fenn, "A Cinematographical Study of Sprinters," Scientific Monthly, 32:346-354, 1931; D. E. Deshon and R. C. Nelson, "Analysis of Sprint Running," The Research Quarterly, 35:451, December, 1964; William Footrick, "An Analysis of Javelin Throwing" (unpublished Master's thesis,

Ganslen[34] studied top pole vaulters to determine the best form suited for vaulting efficiency. He made comparisons of stride, pole plant, timing of the pole shift, take-off velocity, path of center of gravity, and clearance of eight eastern vaulters.

Abbot[35] used films to analyze the hurdling techniques used by three of the world's leading hurdlers. Cureton[36] analyzed the mechanics of the shot put, high jump, broad jump, sprinters start, and running, while Memory and Cornell[37] studied the propelling force and kinetic energy involved in the shot put.

Springfield College, Springfield, Massachusetts, 1938), 99 pp.; W. Knight and F. Hepp, "Mechanical Analysis of the Track Racing Start" (unpublished project, Department of Applied Physics and Body Mechanics, Springfield College, Springfield, Massachusetts, 1935), 50 pp.; Vernon W. Lapp, "A Study of Hammer Velocity and the Physical Factors Involved in Hammer Throwing," The Research Quarterly, 6:3, October, 1935; Thomas K. Cureton, Jr., "Mechanics of the Track Racing Start," Scholastic Coach, 4:14-15, January, 1953.

[34] Richard V. Ganslen, "A Mechanical Analysis of the Pole Vault" (unpublished Master's thesis, Springfield College, Springfield, Massachusetts, 1940), 53 pp.

[35] Richard R. Abbot, "A Cinematographical Analysis of the Techniques of Hurdling" (unpublished Master's thesis, University of Illinois, Urbana, 1948), 90 pp.

[36] Thomas K. Cureton, Jr., "Mechanics of the Shot Put," Scholastic Coach, 4:7-10, March, 1953.

[37] H. N. Memory and D. D. Cornell, "An Analysis of Propelling Force and Kinetic Energy Involved in the Shot Put" (unpublished project, Department of Applied Physics and Body Mechanics, Springfield College, Springfield, Massachusetts, 1935), 23 pp.

Ehrhart[38] found that a survey of the related literature in this area indicated an increase in recent years in obtaining scientific data and principles through the medium of cinematographical research.

IV. MECHANICS OF RUNNING

Cureton[39] avowed that the laws of physics and mechanics govern body efficiency in all activity. He contended that the body, an epitome of efficient construction, used mechanical principles to produce performance in running, one of the oldest of athletic activities. Muscle force, depending upon strength and mechanical leverage, is transmitted to the bones to produce either force or speed. The external mechanics represent form. This was usually dependent upon the angle of application of force to the ground, how the movements were controlled in direction, the carriage and alignment of the body, and the timing which produced optimum power and economy for the particular race. These criteria, easily seen by looking at the runner, were governed by a mechanical principle. In other words, form was synonomous with mechanics. Slocum and Bowerman[40]

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[38] Ehrhart, op. cit., p. 16.

[39] Thomas K. Cureton, Jr., "Mechanics of the Shot Put," Scholastic Coach, p. 8.

[40] Donald B. Slocum and William Bowerman, "The Biomechanics of Running," National Conference on the Medical Aspects of Sports Proceedings, 1966, pp. 53-55.

explained the mechanics of running as follows:

> The patterns and types of running are so varied that it would be presumptious to think that anything other than general principles could be discussed here. Basically the objective of running is to gain increased speed and mobility. Speed is dependent on the length of the stride times the number of strides per minute. . . . The distance covered by the runner in the phase of support is limited to the distance covered by the body as it pivots over the lower extremity. This is, of course, enhanced by the flexibility of the spine which permits the runner to reach further backward at the time of take-off. . . . The distance spanned during the period of float is greater than that during the period of support and may be varied at the will of the runner by the force exerted at the time of take-off. Take-off starts at the time when the center of gravity passes forward of the metatarsal heads in the ball of the foot and ends when the foot leaves the ground. . . . OK
>
> The body posture in running is adapted to the purpose of the sport. In track, speed and endurance alone are required, for the center of gravity is little affected by outside forces and movement consists essentially of straight forward motion. Therefore the trunk is carried in an upright position and the feet track directly under the body along the line of progression, and equilibrium is maintained through postural control.
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> . . . .
>
> In the frontal plane side-to-side sway should be kept at a minimum to lessen the burden borne between postural muscles in maintaining equilibrium, and to maintain the trunk in a position of greatest working efficiency. . . .
>
> In looking at the runner from the side, the hip and knee of the leading leg are in maximum flexion at the time of take-off, then go into partial extension--the degree varying with the individual runner. The entire leg must be moving strongly backward at the time of foot strike in order to lessen resistance at impact and avoid deceleration. This backward movement is imperative for two reasons. The first, of course, is obvious. If the leg were not moving backward, the forward movement of the runner would cause it to thrust against the ground as it struck. The second is a matter of having the foot more nearly under the body at the time of impact. A simple force diagram will reveal that the farther ahead of the

body the foot strikes the ground, the more acute the angle of the leg with the ground and the greater the deceleration from ground resistance. . . . The position of the trunk as viewed from the side should be ~~essentially~~ erect, for this position favors the flat-backed position ~~of the lumbar spine~~ in mid-stance preparatory to take-off, requires less effort in maintaining postural equilibrium, and provides good respiratory position and free movement of the scapula on the thoracic track.

Many authors have analyzed running and other activities where running was involved. Cureton,[41] Bowerman, Hubbard, Deshon, Fenn, Bunn, Plagenhoef, Ehrhart, and numerous others have made studies or contributions in the area of mechanics of running. Plagenhoef,[42] Fenn, and others have made studies on center of gravity, work, kinetics, and friction in running.

Ehrhart[43] found that in analyzing the external mechanics

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[41] Thomas K. Cureton, Jr., "Mechanics of the Shot Put," Scholastic Coach, pp. 7-10; W. J. Bowerman, "Mile Mechanics and Training Techniques," Athletic Journal, 40:8-9+, January, 1960; Hubbard, op. cit., pp. 133-138; Deshon, op. cit., p. 451; W. O. Fenn, "A Cinematographic Study of Sprinters," Scientific Monthly, pp. 346-354; W. O. Fenn, "Work Against Gravity and Work Due to Velocity Changes in Running," American Journal of Physiology, 92:433-462, 1930; W. O. Fenn, "Frictional and Kinetic Factors in the Work of Sprint Running," American Journal of Physiology, 92:583-611, April, 1930; John W. Bunn, Scientific Principles of Coaching (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1955), pp. 103-104, 275-292; Stanley C. Plagenhoef, "Methods for Obtaining Kinetic Data to Analyze Human Motions," The Research Quarterly, 37:103-112, March, 1966; Ehrhart, op. cit., p. 27.

[42] Plagenhoef, ibid., pp. 103-112; W. O. Fenn, "Work Against Gravity and Work Due to Velocity Changes in Running," American Journal of Physiology, p. 433; W. O. Fenn, "Frictional and Kinetic Factors in the Work of Sprint Running," American Journal of Physiology, p. 583; W. O. Fenn, "A Cinematographic Study of Sprinters," Scientific Monthly, pp. 346-351.

[43] Ehrhart, op. cit., p. 26.

of running, the recovery of the leg, the angle the leg makes with the center of gravity of the body as it touched down on its power stroke, the length of stride or cycle, body lean, and angles of arms during the power stroke were key areas. Bresnahan and Tuttle[44] said that in recovery of the leg, the most economical way was to bring the foot high under the buttocks to lessen the effort of bringing the leg forward. Fenn[45] found that a runner hits the ground in front of his center of gravity creating an average loss of 1-1/2 per cent of his velocity every time one foot hits the ground. Steindler[46] and Bunn and Slocum and Bowerman were in disagreement on just how much body lean a runner should have. Bunn felt that about twenty degrees were needed to overcome air resistance and keep the center of gravity ahead of the striding foot. Slocum and Bowerman felt that a more erect position was better because it provided a good respiratory position and free movement of the scapula on the thoracic track and made the postural muscles support instead of balance the top 60 per cent of body

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[44]George Bresnahan and W. W. Tuttle, Track and Field Athletics (St. Louis, Missouri: C. V. Mosby Company, 1937), p. 283.

[45]W. O. Fenn, "A Cinematographic Study of Sprinters," Scientific Monthly, p. 348.

[46]Arthur Steindler, Kinesiology of the Human Body (Iowa City: Charles C. Thomas, Publisher, 1955), p. 631; Bunn, op. cit., p. 111; Slocum and Bowerman, op. cit., p. 55.

weight. In studies by Hubbard,[47] Deshon, Fenn, Steindler, and Bowerman, the emphasis on analysis of running was placed on body lean, body angles, and length of stride. These authors and others recommended the use of the following markings for more reliable and valid measurements: tip of toes, the outer malleolus, center of the hip, knee, shoulder, tragus of the ear, center of the elbow and wrist, and the tip of the middle finger.

V. TREADMILL

Peizer[48] stated that almost all areas of physiological and fitness testing have used the treadmill. A great many researchers have made it a part of their testing and included it in their publishings. Yet, no mention of reliability, validity, or mechanical studies to support the use of a treadmill as a substitute for controlled running was found. In 1931 Lumley[49] wrote that the treadmill was originally built

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[47] A. W. Hubbard, "An Experimental Analysis of Running and of Certain Fundamental Differences Between Trained and Untrained Runners," *The Research Quarterly*, 3:28-39, 1939; A. W. Hubbard, "Photography," *Research Methods in Health, Physical Education, and Recreation*, p. 136; Deshon, *op. cit.*, p. 10; W. O. Fenn, "A Cinematographic Study of Sprinters," *Scientific Monthly*, p. 350; Steindler, *op. cit.*, p. 631; Bowerman, *op. cit.*, p. 8.

[48] Edward Peizer, "An Evaluation and Physiological Analysis of Selected Shuttle Runs" (unpublished Doctoral dissertation, New York University, New York, 1952), p. 7.

[49] A. E. Lumley, "Breathing Movements in Running" (unpublished thesis, Oberlin College Library, 1931), p. 12.

to study running and breathing movements. Hubbard[50] used a treadmill in 1939 with a recording apparatus designed to show the nature of the movements and the action of the muscles in producing the movements. In 1951 and 1952 at New York University, two studies were made comparing treadmill running to various shuttle runs, both physiologically and through performance in general. Peizer[51] found no significant relationships between the 50-, 150-, and 200-yard shuttle runs and the treadmill, while Brown[52] found no relationships between the mile shuttle run and treadmill running.

In an interview with the head track coach at the University of New Mexico, Hugh Hackett[53] stated a belief that the treadmill encourages mechanics and form that are different from running and possibly harmful in the training of athletes.

VI. SUMMARY

Chapter II is a review of the literature. This review included a history of cinematography and some of the early

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[50] A. W. Hubbard, "An Experimental Analysis of Running and of Certain Fundamental Differences Between Trained and Untrained Runners," The Research Quarterly, p. 28.

[51] Peizer, op. cit., p. 27.

[52] Roscoe C. Brown, Jr., "An Evaluation and Physiological Analysis of the Mile Shuttle Run" (unpublished Doctoral dissertation, New York University, New York, 1951), p. 19.

[53] Statement by Hugh Hackett, personal interview, April 12, 1967.

workers in the field; photographic equipment and its potential; problems encountered in cinematography and methods of countering error; the mechanics of running; treadmill research; and a report of one expert's opinion regarding treadmill and track running.

CHAPTER III

PROCEDURES

I. INTRODUCTION

The major research method used in conducting this study was cinematography, the recording of external body movement upon motion-picture film.

Cinematographical studies have been increasing in the area of human movement and behavior. Cureton[54] maintained that the use of these studies in the analysis of athletic performance has increased for the following reasons:

"1. To estimate the major factors governing performance and their relative importance.

2. To derive the scientific principles of coaching, including an understanding of the physical mechanics of the skill.

3. To lay the basis for a philosophical interpretation of athletic performance based upon relatively accurate theoretical consideration subject to some degree of verification."

Difficulty in analyzing human movement is encountered when watching a runner perform at full speed. Through the use of cinematography, the movements of a runner may be stopped

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[54] T. K. Cureton, "Elementary Principles and Techniques of Cinematographical Analysis as Aids in Athletic Research," The Research Quarterly, p. 3.

in any position for a minute examination by studying individual frames. This enhances the possibility of studying body lean, the various angles of the extremities, length of stride, and average vertical body movement.

II. GENERAL DESIGN

The subjects chosen were individuals who ran either sprints or distances on the University of New Mexico track team. Three sprinters and three distance runners were chosen to provide an overall picture of running styles for analysis. The main objective of the study was to have each runner filmed running comfortably at the same speed on the treadmill and on a stationary surface. The two film strips of each runner were analyzed and compared. All marks were placed on the left side of each runner. Thus, all measurements were taken of the extremities on the left side.

III. SUBJECTS

Since the subjects in this study were trained track men, it might be apropos to include some of their performance times as well as their vital statistics in painting a picture of the people involved in this study.

Subject A. Subject A was twenty-one years old, seventy-four inches tall, and weighed 160 pounds. The best times made by this individual were: 9.6 seconds for the 100-yard dash;

21.2 seconds for the 220-yard dash; and 46.9 seconds for the 440-yard dash.

Subject B. Subject B was twenty years old, seventy-two inches tall, and weighed 182 pounds. The best times made by this individual were: 9.4 seconds for the 100-yard dash; 21.0 seconds for the 220-yard dash; and 47.3 seconds for the 440-yard dash.

Subject C. Subject C was twenty years old, sixty-nine inches tall, and weighed 150 pounds. The best times made by this individual were: 4:13 minutes for the mile and 1:52 minutes for the 880-yard run.

Subject D. Subject D was twenty years old, seventy-four inches tall, and weighed 160 pounds. The best times made by this individual were: 1:56 minutes for the 880-yard run; 4:19 minutes for the mile; and 9:30 minutes for the two-mile run.

Subject E. Subject E was twenty years old, 70.5 inches tall, and weighed 163 pounds. The best times made by this individual were: 1:49 minutes in the 880-yard run and 46.0 seconds in the 440-yard dash.

Subject F. Subject F was twenty years old, seventy inches tall, and weighed 150 pounds. The best times made by this individual were: 6.0 seconds in the sixty-yard dash and

9.4 seconds in the 100-yard dash.

IV. TREADMILL RUN

The treadmill in the Human Performance Laboratory at the University of New Mexico was located in a room with limited space. Hence, a wide-angle lens was necessary to encompass the entire body of the runner. A wide-angle lens, at an f stop of two, and a Pathe model PR16-AT/BTL 16 mm. high-speed camera were used with a full shutter opening at eighty frames per second. The camera was placed at a maximum measured distance from the treadmill. This distance was nine feet from a line six inches to the right of the center of the treadmill to the camera lens. The camera was placed at the best height to focus on the full length of the runner. The tripod setting and height were marked for future use. The height was 39-3/4 inches and marks were made on the floor around the tripod legs. A standard No. 2 bulb photoflood lamp was used to raise the light in the room to a proper level. To make sure the same speed was used for each runner, the camera was rewound before each cycle was taken. A 100-foot reel of Kodak black-and-white film was used. Tri-X film was used indoors on the treadmill, and Plus-X film was used outdoors. A special backdrop was placed at a closely measured distance of 40-1/4 inches from the line in the center of the treadmill and opposite the camera. This backdrop was a white sheet spread tightly between two

volleyball standards to provide a contrasting surface. A plumb line was used to produce a vertical line on the backdrop, and a one-foot ruler was attached to the lower leg to provide

FIGURE 1

TREADMILL RUNNING

a scale reference for measuring distance. Lines thirty-six inches apart were made upon the treadmill surface by using 1-1/2-inch tape and measuring from the front of each strip.

These lines were used to determine the length of stride and distance from touchdown to a line extended vertically from the center of the ilium as shown in Figure 1.

A speed of 8.168 miles per hour was set on the treadmill, and the treadmill was leveled to a grade of zero per cent. Each runner was given a familiarization program of three 2-minute practice runs to get acquainted with the action and speed of the treadmill. The runners were told to remove their shirts, and a special white marking spot for Negroes and red for Caucasians was placed on the left lateral epicondyle of the elbow, the lateral condyle of the knee, the outer malleolus of the ankle, the tragus of the ear, and the middle outer edge of the iliac crest. After a three-minute warmup and accustomization to the treadmill, the runners were told to settle into a comfortable stride with the treadmill moving at 8.168 miles per hour at a zero per cent grade.

V. STATIONARY SURFACE RUN

The stationary surface run was set up on the varsity track at University Stadium on the west straightaway with the runners facing the north. The same type of backdrop that was used in the treadmill run was erected at the north end of the west straightaway. It was approximately eighteen-feet long and constructed of two large bed sheets and three volleyball standards. The backdrop was erected exactly as the one for the treadmill with an exact distance of 40-1/4 inches being

measured between the backdrop and the line the runner ran along and eighteen-feet long to encompass two full strides. This line was laid out along the inside edge of the track with

FIGURE 2

STATIONARY RUN I

regular track lime. A piece of white canvas with carefully marked dark perpendicular lines thirty-six inches apart was placed along the runner's line throughout the length of the backdrop for measurement of length of stride. The camera was

mounted in the right front window of a 1961 Bel Air Chevrolet at exactly the same height, 39-3/4 inches, as was used on the treadmill. The distance from the runner's line to the camera lens was carefully marked off at nine feet, and the line to guide the car was then marked to line up with a mark on the windshield and a mark on the left front fender as pictured in Figure 2. The driver then steered the car along this white line keeping the camera a standard distance from the runner at all times. Another person sat in the front seat of the car, and while sitting along the line of the camera, pressed the gas pedal to keep the car exactly at the side of the runner. A separate individual sat in the right back seat and started the camera just after passing the backdrop. The camera was equipped with a wide-angle lens and was set at an f stop of ten and one-quarter shutter opening at eighty feet per second was employed. Note Figure 3.

To get the same speed in both runs, a pacer was constructed. This pacer was made by acquiring a 1,200 rpm set-speed motor and constructing a special metal reel to fit the motor spindle and take up a 1/32 size fishing line at a certain speed. The diameter of the reel was machined down to 2.27 inches, and the motor was placed on a short, stable platform. The motor was placed at the north end of the straightaway on the inside of the infield in front of the backdrop. The pacer itself was a small telephone insulator with a red flag attached

that was pulled along a 150-foot wire strung between two stakes on the infield of the straightaway.

FIGURE 3

STATIONARY RUN II

To obtain the exact speed of the pacer, a distance of 100 feet was set up on the wire; and using a Model 631 automatic performance analyzer, twelve timings were taken of the pacer over this distance. A 100-foot line was attached to both the

pacer and a small chip of wood that stopped the analyzer when pulled away from it. A button was pushed to start the analyzer as the pacer passed a certain mark. The highest and lowest timings were discarded, and the other ten were averaged to give 8.34 seconds per hundred feet which was converted to 8.168 miles per hour. Note Figure 4.

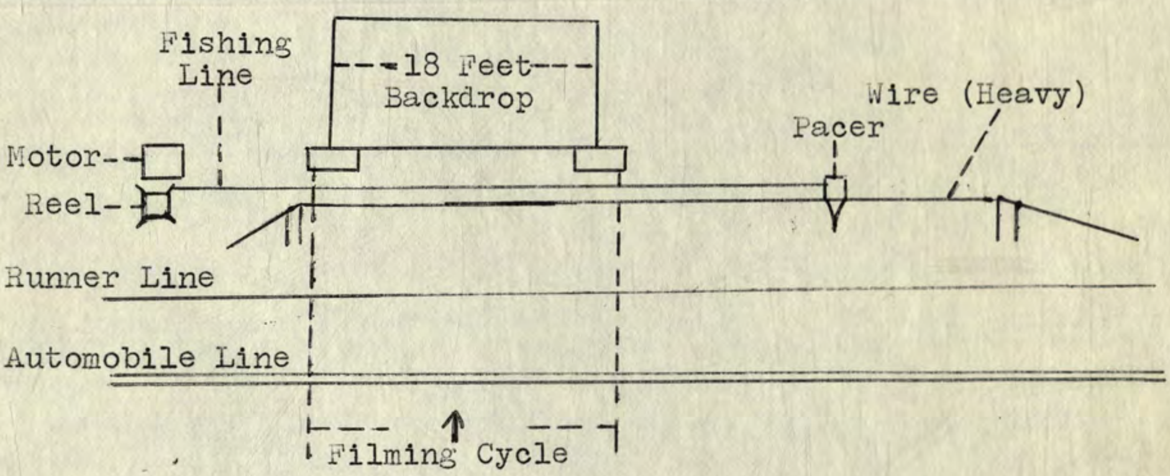

FIGURE 4

DIAGRAM OF STATIONARY RUN SET UP

The runner ran along the line on the track in his own natural stride keeping pace with the pacer. The car stayed alongside the runner and filmed his strides through the backdrop.

A pilot experiment was completed using full facilities and equipment on both the treadmill and stationary run prior to the beginning of actual filming. A check of the procedures used was obtained by using a small frame analyzer. The procedures and techniques tested in the pilot study proved satisfactory.

VI. METHOD OF PROJECTION

A special grid was constructed to use as a screen employing a white, four foot by six foot bulletin board. Carefully drawn lines were placed horizontally and vertically to form six-inch squares.

A special stop-action projector was obtained so each frame could be stopped and held for measurement as long as necessary. A Bell and Howell Filmosound Specialist 542 with a wide-angle lens was used. The projector was centered on the screen by measuring the distance from the lens to the floor and from the lens to a wall rising perpendicular to the left of the screen and lens. A level was used on the projector and the screen to make the angle of projection perpendicular to the screen.

In stopping the projector on an individual frame, the light automatically dimmed, producing a slightly darker reflection of somewhat poorer quality.

VII. METHOD OF ANALYZING FILM

The frames were projected onto the grid screen, and moving through each runner's film strip, the point where each measurement was at its optimum position in the stride was measured. All measurements taken were recorded for future analysis. To allow for changes in length of stride and to equalize the measurements as much as possible, these measurements

were taken only at specific instances: such as moment of highest leg lift, leg touchdown.

The runners were marked as previously described, and using these marks, a variable right triangle was employed to determine the angles involved.

VIII. ANGULAR MOVEMENTS

In the angular measurements, a variable right triangle was placed on either a horizontal or vertical line in measuring the angle of leg lift, angle of leg at touchdown, forward and backward arm lift as measured by the upper arm, angle of leg at liftoff, and body lean. In measuring the angles between upper and lower arms, and upper and lower legs, the variable right triangle was used to measure between these two sections of the limbs as in Figures 5 and 6. Large-headed straight pins were placed in the center of the special markings for maximum accuracy.

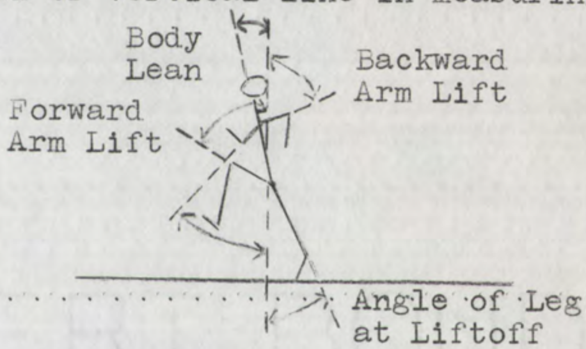

FIGURE 5

ANGULAR MEASUREMENTS OF LEGS, ARMS, AND BODY

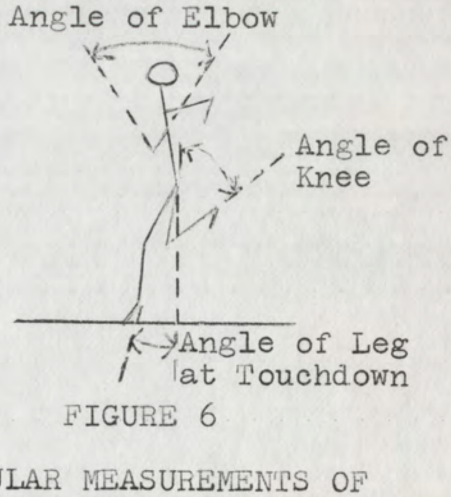

FIGURE 6

ANGULAR MEASUREMENTS OF ELBOW, KNEE, AND LEG

IX. HORIZONTAL MEASUREMENTS

The measurements taken were: calculation of the length of stride, amount of vertical movement while running, and the distance of touchdown forward of a horizontal line through the approximate center of gravity as illustrated in Figures 7 and 8. The measurement of stride was obtained by starting with the back leg fully extended just prior to leaving the ground, and the film was advanced until the same leg was fully extended just as it touched the ground. In figuring the distance, lines perpendicular to the runner's line of flight were placed thirty-six inches apart on both the treadmill and the track. The lines marked were 1-1/2-inches wide, and the distance between lines was taken from the front of the lines. The distance was obtained by measuring the start and finish between

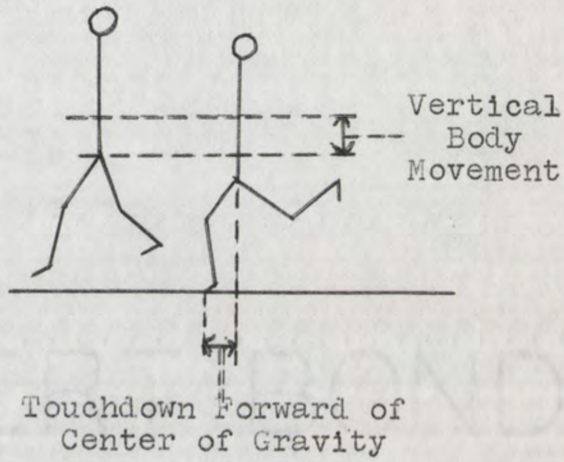

FIGURE 7

HORIZONTAL MEASUREMENTS OF VERTICAL MOVEMENT AND TOUCHDOWN

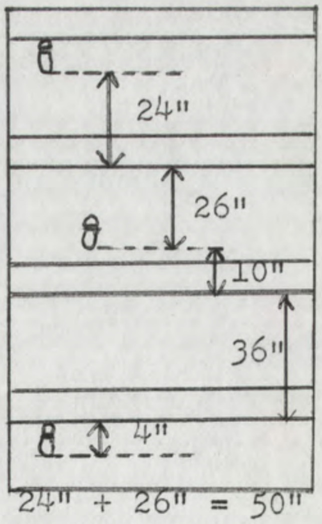

FIGURE 8

HORIZONTAL MEASUREMENT OF LENGTH OF STRIDE

lines and adding the number of lines passed in the stride times thirty-six inches.

The distance of touchdown forward of the estimated center of gravity was measured by finding the distance from a horizontal line through the special mark on the central upper crest of the ilium to the front of the toe upon contact with the surface.

The average amount of up-and-down movement while running was measured by subtracting the distance of the center of the top of the crest of the ilium from the ground at its lowest point from the same measurement at the highest point in relation to the running surface.

X. TREATMENT OF THE DATA

The smallness of the group demanded a method that could be used for handling small samples and still provide a valid estimate of error.

Both groups underwent an analysis of variance to determine whether or not the ratio of the means of the sum of the squares between groups and the means of the sums of the squares within groups was significant when an "F" test was applied.

The analysis of variance between the treadmill and stationary run measurements was programmed for the IBM 360 computer under program 6607. The data were punched on cards

by an IBM key punch machine. The computer analyzed the data in the following manner. The individual scores were totaled to obtain a sum of scores; these were divided by N to produce a general mean score.[55] The mean score was subtracted from each individual score and the difference between each was squared and summed to produce sum of squares for total.

The within groups variance was found for each group by adding the scores and dividing by N to produce the mean score. The mean score was subtracted from each individual score and the difference between each was squared and summed to produce the sum of squares within. The total sum of squares within (SS_n) is found by adding the sum of squares within each group. The between groups variance is obtained by subtracting the overall mean from each subgroup mean. This difference is squared and multiplied by the number of persons in that subgroup. These products are added to obtain the sum of squares between (SS_b). The degrees of freedom for total (DF) were found by taking one less than N. The degrees of freedom for between groups were found by taking one less than the number of groups. The degrees of freedom for within groups was the difference between DF for total and DF for between groups. The mean sum of squares was found by dividing the SS_b and the SS_n by their respective DF. The resultant ratio of the mean squares

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[55] J. G. Cooper, Basic Statistical Analyses for Educational Research (Albuquerque, New Mexico: University of New Mexico College of Education, 1966), pp. 17-33.

between (MS_b) and the mean squares within (MS_n) was the value that must exceed the "F" value at the 5 per cent level of confidence if the hypothesis is to be rejected. Table I gives the full computations for analysis of variance.

TABLE I

COMPUTATIONS FOR ANALYSIS OF VARIANCE

Source	DF	SS	MS	F
Between	a - 1	$n_b d_b^2 + n_g d_g^2$	$(n_b d_b^2 + n_g d_g^2)/(a-1)$	$\frac{\text{Between MS}}{\text{Within MS}}$
Within	N - a	$Sx_b^2 + Sx_g^2$	$(Sx_b^2 + Sx_g^2)/(N-a)$	
Total	N - 1	Sx^2		

XI. SUMMARY

Chapter III was a presentation of the procedures to be followed in the study. A general introduction was followed by a discussion of the general design, the subjects used, discussion of the treadmill, the stationary surface run, the method used in projecting the film, the method of analyzing the film, a discussion of angular movements to be measured, horizontal measurements, and treatment of the data.

CHAPTER IV

PRESENTATION AND ANALYSIS OF DATA

I. INTRODUCTION

The data were collected by filming six subjects on the treadmill and on a stationary surface with a high-speed camera as described in Chapter III.

The film was frame analyzed using eleven measurements as the basis for evaluating the mechanical performance between treadmill running and running on a stationary surface. The data were keypunched on computer data cards and run through the IBM 360 computer at the University Research Center.

II. RELIABILITY OF DATA

Measurements were made as closely as possible. In all cases where there were large differences, another measurement was taken from another stride to corroborate the first measurement and check for errors. These supplementary measurements all corresponded closely with the primary measurements.

III. RAW DATA

The data were placed in a table showing each individual's measurements graphically to illustrate possible overt or obvious differences which appear in Table II.

A separate graph giving the mean of each of the eleven

TABLE II

RAW DATA

RUNNERS	ANGLE OF LEG LIFT	ANGLE OF LEG AT TOUCHDOWN	FORWARD ARM LIFT	BACKWARD ARM LIFT	ANGLE OF LEG AT LIFTOFF	BODY LEAN	ANGLE OF KNEE	ANGLE OF ELBOW	LENGTH OF STRIDE	TOUCHDOWN FORWARD OF CENTER OF GRAVITY	VERTICAL BODY MOVEMENT
Tread. A	25.50°	10.50°	25.00°	50.00°	22.00°	10.50°	74.00°	45.50°	52.70"	14.50"	5.00"
Stat.	28.00°	12.50°	11.50°	49.50°	23.50°	2.70°	69.00°	44.00°	53.50"	14.40"	5.40"
Tread. B	30.00°	16.00°	30.50°	55.50°	25.00°	13.00°	68.50°	55.50°	53.00"	19.20"	4.60"
Stat.	28.00°	12.00°	31.50°	55.50°	34.00°	16.50°	76.00°	68.50°	54.90"	16.50"	4.20"
Tread. C	28.00°	14.50°	10.00°	52.50°	28.00°	12.00°	69.00°	77.50°	56.80"	18.20"	5.40"
Stat.	26.50°	12.50°	11.50°	49.00°	29.50°	8.00°	75.50°	81.50°	51.90"	16.50"	4.50"
Tread. D	25.50°	11.00°	4.50°	50.00°	25.00°	10.00°	96.00°	64.00°	54.20"	15.60"	3.40"
Stat.	29.50°	12.80°	8.00°	64.00°	27.50°	7.70°	83.00°	59.50°	49.50"	17.40"	4.50"
Tread. E	19.00°	9.00°	14.50°	48.50°	28.00°	11.50°	90.70°	69.50°	47.70"	16.50"	4.40"
Stat.	27.50°	10.00°	7.00°	44.00°	28.00°	7.00°	85.50°	65.50°	45.60"	15.90"	4.80"
Tread. F	34.50°	9.00°	0.00	45.50°	27.00°	12.50°	76.50°	67.50°	50.70"	12.70"	3.70"
Stat.	30.00°	12.50°	0.00	47.50°	33.50°	8.00°	76.00°	69.00°	52.90"	15.60"	5.20"
Means	27.08° 28.25°	11.70° 12.05°	14.08° 11.58°	50.30° 51.58°	25.80° 29.30°	11.58° 8.32°	79.10° 77.50°	63.25° 64.70°	52.20" 51.35"	16.10" 16.07"	4.42" 4.77"
Mean Diff.	1.17°	.35°	2.50°	1.28°	3.50°	3.26°	1.60°	1.45°	.85"	.03"	.35"

measurements for both treadmill and stationary runs appears in Table III.

IV. ANALYSIS

The computer furnished a printout with the analysis of variance results. In this analysis of variance with six subjects, eleven variables, and two groups, the degree of freedom for treatments was one and for within was ten. This resulted in the requirement of an "F" score of 4.96 to be significant at the 5 per cent level of confidence. This data appears in Table IV.

In the angle of left leg lift, an "F" score of 0.29 was computed and showed no significant difference. This information appears in Table IV. Mean scores were reported as 27.08 degrees leg lift on the treadmill and 28.25 degrees leg lift on the stationary surface. This difference of 1.17 degrees was not significant statistically. There may be a possibility of some difference in the running mechanics. The leg lift corresponded with vertical body movement in five of the six runners, possibly indicating that the greater the angle of leg lift the more the vertical body movement. Because the treadmill might require less work and less movement by the subject to run at the same speed, the higher angle of leg lift on the stationary surface would be expected. These data appear in Table II on page 41.

TABLE III

GRAPHIC PRESENTATION OF RAW DATA

	Treadmill	Stationary Surface	Difference
Angle of Leg Lift	27.08°	28.25°	1.17°
Angle of Leg at Touchdown	11.70°	12.05°	.35°
Forward Arm Lift	14.08°	11.58°	2.50°
Backward Arm Lift	50.30°	51.58°	1.28°
Angle of Leg at Liftoff	25.80°	20.30°	3.50°
Body Lean	11.58°	8.32°	3.26°
Angle of Knee	79.10°	77.50°	1.60°
Angle at Elbow	63.25°	64.70°	1.45°
Length of Stride	52.20"	51.35"	.85"
Touchdown Forward of Center of Gravity	16.10"	16.07"	.03"
Vertical Body Movement	4.42"	4.77"	.35"

TABLE IV

THE ANALYSIS OF DIFFERENCES BETWEEN RUNNING ON A TREADMILL AND A STATIONARY SURFACE

Measurements	Analysis of Variance				
Angle of Leg Lift	Source	DF	SS	MS	F
	Treatments	1	408.30	408.30	.29
	Within	10	14,310.00	1,431.00	
	Total	11	14,720.00		
Angle of Leg at Touchdown	Source	DF	SS	MS	F
	Treatments	1	44.08	44.08	.09
	Within	10	4,821.00	482.10	
	Total	11	4,865.00		
Forward Arm Lift	Source	DF	SS	MS	F
	Treatments	1	1,875.00	1,875.00	.15
	Within	10	126,000.00	12,600.00	
	Total	11	127,900.00		
Backward Arm Lift	Source	DF	SS	MS	F
	Treatments	1	468.80	468.80	.15
	Within	10	31,300.00	3,130.00	
	Total	11	31,770.00		
Angle of Leg at Liftoff	Source	DF	SS	MS	F
	Treatments	1	3,675.00	3,675.00	3.49
	Within	10	10,520.00	1,052.00	
	Total	11	14,190.00		
Body Lean	Source	DF	SS	MS	F
	Treatments	1	3,201.00	3,201.00	2.98
	Within	10	10,750.00	1,075.00	
	Total	11	13,960.00		

TABLE IV (cont.)

Measurements	Analysis of Variance				
Angle of Knee	Source	DF	SS	MS	F
	Treatments	1	784.10	784.10	.09
	Within	10	84,230.00	8,423.00	
	Total	11	85,020.00		
Angle at Elbow	Source	DF	SS	MS	F
	Treatments	1	602.10	602.10	.04
	Within	10	140,700.00	14,070.00	
	Total	11	141,300.00		
Length of Stride	Source	DF	SS	MS	F
	Treatments	1	234.10	234.10	.22
	Within	10	10,530.00	1,053.00	
	Total	11	10,770.00		
Touchdown Forward of Center of Gravity	Source	DF	SS	MS	F
	Treatments	1	.75	.75	0.00
	Within	10	3,382.00	338.20	
	Total	11	3,383.00		
Vertical Body Movement	Source	DF	SS	MS	F
	Treatments	1	36.75	36.75	.93
	Within	10	394.20	39.42	
	Total	11	430.90		

The angle of leg at touchdown produced mean scores of 11.7 degrees on the treadmill and 12.05 degrees on the stationary surface for a difference of 0.35 degrees. An "F" score of 0.09 was computed which indicated no significant difference.

This small difference in means did not give a true picture of the individual differences as illustrated in the raw data in Table II on page 41. All subjects showed a difference of from 1.0 to 4.0 degrees but not in the same direction. The angle of touchdown on the stationary surface varied from 10.0 degrees to 12.8 degrees while the treadmill measurements varied from 9.0 degrees to 16.0 degrees. This could possibly indicate that a larger variance in running form is employed on the treadmill because of the possible relative nonimportance of efficiency and technique in placing the foot on a moving surface as compared to a stationary surface.

The forward left arm lift and backward left arm lift both computed an "F" score of 0.15 which was not statistically significant. In the forward arm lift, mean scores of 14.08 degrees in the treadmill and 11.58 degrees in the stationary run produced a difference of 2.5 degrees. The backward arm lift had mean scores of 50.3 degrees on the treadmill and 51.58 degrees on the stationary run for a difference of 1.28 degrees as shown in Table II on page 41. In studying the raw data, it was found that those subjects having large differences in the

forward arm lift also had, on the whole, the larger differences on the backward arm lift. This would seem to indicate that an adjustment in balance and running form had been employed by these runners. Another indication might be that these same subjects had more body lean on the treadmill.

The angle of leg at liftoff came the closest to being statistically significant with an "F" score of 3.49. This was not significant; yet all runners but one had a higher angle of leg lift on the stationary surface and he had the same angle for both. Mean scores were 25.8 degrees for the treadmill and 29.3 degrees for the stationary surface. This difference of 3.5 degrees was too consistent in being a lower liftoff angle on the treadmill, and with it being significant at the 7 per cent level, it was too high above chance to be left unquestioned. This again could be an indication of the subjects having done less work on the treadmill because their leg extension in pushoff was not as great as that in the stationary run.

Body lean had an "F" score of 2.98 which was not statistically significant, yet showed enough difference to warrant a closer investigation. The mean scores were 11.58 degrees on the treadmill and 8.32 degrees on the stationary surface. This produced a difference of 3.26 degrees, which in all cases but one was higher on the treadmill. This could have been a possible indication of the subjects leaning into the belt and relying on the treadmill to provide some of the power and reduce the runner's work load.

The difference in angle of the knee was computed to an "F" score of 0.09 which was not statistically significant. The mean scores were 79.1 degrees for the treadmill and 77.5 degrees for the stationary surface. A difference in means of 1.6 degrees did not tell the entire story. Individual differences varied from 0.5 degrees to 13 degrees, and the treadmill had a range of scores from 68.5 degrees to 96.0 degrees as compared with the stationary surface range of 76.0 degrees to 85.5 degrees. This may have indicated the possibility of more varied or inefficient running on the treadmill because of the lack of necessity to work as hard.

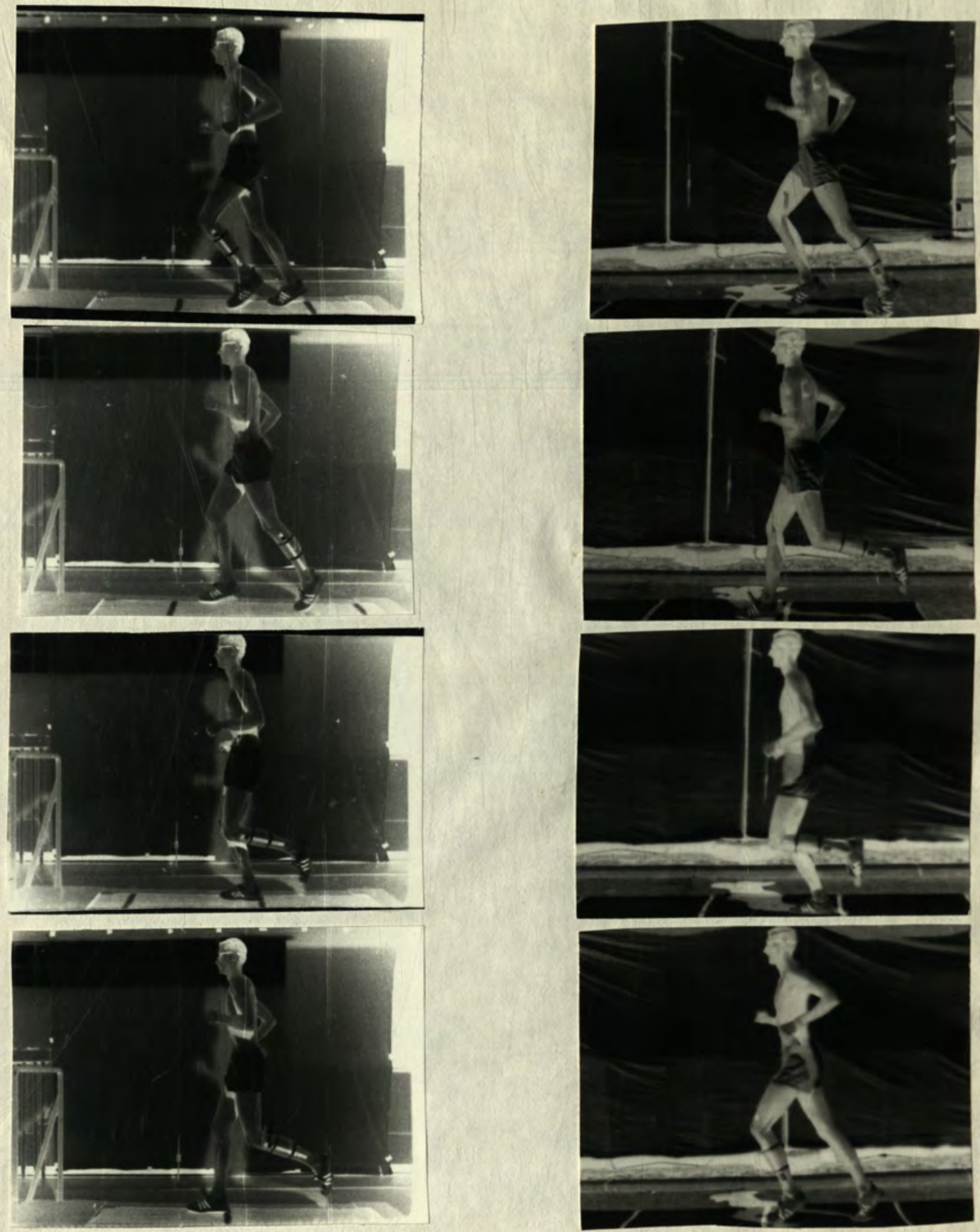
The "F" score for angle of elbow was 0.04 and not significant. The mean scores were 63.25 degrees for the treadmill and 64.7 degrees for the stationary run. A noted lack of consistent variance in the raw data and mean scores could be an indication that the lower arm might not have been employed too extensively at this slow speed, resulting in close correlations in measurements.

The length of stride had an "F" score of 0.22 which was not significant. The mean scores of 52.2 inches on the treadmill and 51.35 inches on the stationary surface produced a mean difference of 0.85 inches. The largest individual difference in length of stride was 4.9 inches. This was an indication that the speed in both cases was close to being equal and that the runners were covering the same distance in

the same amount of time in both cases.

Touchdown forward of the center of gravity had an "F" score of 0.00 which was not significant. The mean scores were 16.1 inches on the treadmill and 16.07 inches on the stationary surface. This difference of 0.03 inch is not a good indication of possible differences. The range of scores on the treadmill varied from 12.7 inches to 19.2 inches, while on the stationary surface, the scores varied from 14.4 to 17.4 inches. This difference in the amount of variance in scores could indicate a larger variance of movement on the treadmill. The individuals ranged in differences from 0.5 inches to 2.9 inches which in a trained runner would appear to be a tremendous change in efficiency of movement.

Vertical body movement had an "F" score of 0.93 which was not statistically significant. Mean scores were 4.42 inches on the treadmill and 4.77 inches on the stationary surface for a difference of 0.35 inches. The individual differences varied from 0.4 inches to 2.5 inches which is not reflected in the mean difference. Though the measurements show a lack of consistency in one direction, the range of measurements of vertical body movement--3.7 inches to 5.5 inches on the treadmill and 4.2 inches to 5.2 inches on the stationary run--indicate a consistently greater variance in the treadmill scores. This could be another possibility of inefficient running mechanics. Figure 9 shows an individual



Treadmill | Stationary Run

FIGURE 9

TREADMILL AND STATIONARY RUN SEQUENCES

in two sequences of four frames each running on the treadmill and on the stationary surface.

The factor of a larger variance in treadmill running may be caused by the runners having less experience or skill in treadmill running. It may also be that with more training and practice on the treadmill the runner may become more efficient at treadmill running which would produce greater differences, if any exist, between treadmill and stationary surface running.

This group of trained runners may have had fewer differences in comparing the two methods of running because of their high level of training and efficiency. It was possible that the habits instilled through intensive training may have overriden any differences that the treadmill might have produced.

CHAPTER V

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

I. SUMMARY

It was the purpose of this study to evaluate, through a cinematographical analysis, if running on a treadmill produced a change in running style or form by comparing body lean, various angles of the extremities, length of stride, and vertical body movement.

It was hypothesized that a cinematographical study of a group of individuals running on a motor-driven treadmill and on a stationary surface will reveal no significant mechanical differences in performance.

Terms unique to this study were defined. The literature was reviewed and discussed under the history of cinematography, equipment used, problems encountered, photographic methods, mechanics of running, and treadmill research.

The procedures to be followed in this study were presented. This discussion included the subjects used, the treadmill and stationary surface running, the methods used in projecting and analyzing the film, a discussion of angular and horizontal movements to be measured, and treatment of the data.

The presentation and analysis of the data appear in Chapter IV.

II. CONCLUSION

Within the limitations of this study, the following conclusion seems justified: There were no statistically significant differences found between running on the motor-driven treadmill and the stationary surface as determined from the stated eleven measurements.

III. RECOMMENDATIONS FOR FURTHER STUDY

1. A study should be conducted to obtain differences in the magnitude of the joint forces and the moments of force between treadmill and stationary running.

2. A study should be conducted to obtain differences in work force factors between treadmill and stationary running.

3. A study should be conducted to find what relationship exists between velocity of running and consistency of form.

4. A study should be conducted to find what relationship exists between velocity of running and the flexibility of the body segments involved in running.

5. A similar study should be conducted with a larger sample of runners.

6. An oxygen cost study should be conducted to obtain differences between treadmill and stationary running.

7. A study should be conducted to examine the differences that exist within the runner himself in performing on the treadmill and a stationary surface.

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