AN ANTHROPOMETRIC ANALYSIS OF THE OS CALCANEUS IN AMERICAN NEGROES AND CAUCASIANS AND ITS IMPLICATIONS FOR ANKLE JOINT MECHANICS

A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

THE DEGREE OF MASTER OF ARTS IN PHYSICAL EDUCATION

IN THE GRADUATE DIVISION OF THE

TEXAS WOMAN'S UNIVERSITY

COLLEGE OF HEALTH,

PHYSICAL EDUCATION AND RECREATION

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DENTON, TEXAS
JUNE, 1969

Texas Woman's University

Denton, Texas

JUNE 19 69

We hereby recommend that the thesis prepared under our supervision by ELIZABETH A. STASSWENDER entitled AN ANTHROPOMETRIC ANALYSIS OF THE OS CALCANEUS IN AMERICAN NEGROES AND CAUCASIANS AND ITS IMPLICATIONS FOR ANKLE JOINT MECHANICS

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ACKNOWLEDGMENTS

The writer feels the deepest appreciation and gratitude to the following people who were instrumental in the evolution of this work:

To Richard V. Ganslen, as thesis director, for his unfailing support and encouragement;

To Claudine Sherrill and Joel Rosentsweig, members of the thesis committee, for their assistance and enthusiasm;

To George Vose, Virginia Brewer, and Jean Bowers for their excellent technical assistance;

To the students who participated in this study for their interest and cooperation;

To my parents whose contributions are too numerous to be listed;

To my roommate who patiently and cheerfully withstood the tensions surrounding the completion of this thesis.

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CHAPTER I

INTRODUCTION

Of the large number of amateur and professional athletes participating in sports involving speed and jumping ability, an unusual proportion are of Negro lineage. That the Negro individual is successful in these endeavors is beyond doubt. One has only to examine the results of the track events of the 1968 Olympics for examples of outstanding achievement by Negro athletes. Track stars Bob Beamon, Jim Hines, Lee Evans, Willie Davenport, Tommie Smith, and Wyomia Tyus all won gold medals for the United States in their events. Black athletes from Kenya, Ethiopia, and Tunisia also won gold medals in track events.[1] Many stars in professional basketball are Negro men: Bill Russell, Wilt Chamberlain, Sam Jones, and others. Recently, an all-Negro basketball team won a second consecutive state championship for boys of high school age.[2] Finally, the list of Negro athletes in professional football is long and star-studded.

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[1] "Summary of the 1968 Olympics," Sports Illustrated, November 4, 1968, pp. 92-96.

[2] The Austin American-Statesman, Sports Section, March 9, 1969, p. 1.

A postulation about the success of Negro athletes has been that these individuals possess longer heels than do the Caucasian athletes. The longer heel directly implies a longer os calcaneus for the Negro than for the Caucasian.

One of the earliest, if not the earliest, observation that the Negro has a longer os calcaneus than the Caucasian was that of a French physiologist, E. H. Marey.[1] Publishing his hypothesis in 1889, Marey speculated that the os calcaneus of the Negro must be some forty per cent longer than that of the Caucasian. He arrived at this conclusion after observing that the calf of the Negro was slimmer than the calf of the Caucasian; by so concluding he also implied an inverse relationship between the length of the os calcaneus and the girth of the calf.

The controversy over the length of the os calcaneus has persisted for eighty years. Attempts have been made in previous investigations, reported in a following section in this chapter, to study the length of the heel. A major problem inherent in these studies has been the consistency with which the lateral or medial malleolus can be located for use as a reference point. Another innate problem in heel measurement is the presence of the calcaneal pad, which artifically adds length to the heel and which is

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[1]Marey, Arch. de Physiol. (1889), as cited by Jules Amar, The Human Motor, trans. by Elsie P. Butterworth and George F. Wright (New York: E. P. Dutton and Company, 1920), p. 122.

impossible to eliminate if external measuring techniques are used. Unfortunately, the calcaneal pad does not contribute to the mechanics or physiology of running and jumping. The present investigation, herein reported, has surmounted both of these major difficulties by the development of new techniques for anthropometry. The research design encompassed an analysis of x-ray negatives of the os calcaneus with provision for correcting magnification errors. In this manner definite reference points were established, permitting accurate measurement of the os calcaneus and of the calcaneal pad.

Anatomy of the Ankle

The ankle is a complex of bones, joints, muscles, and ligaments that facilitates erect posture and locomotion. The bones of the ankle and their relationships to one another are as follows. The tibia of the lower leg forms a ginglymus joint with the talus. The talus in turn articulates with the os calcaneus in three places, the joints being of the gliding type. Both the talus and the os calcaneus articulate with bones of the foot: the talus with the navicular medially and the os calcaneus with the cuboid laterally. The talus forms the keystone of the ankle and is devoid of muscle attachments. Numerous ligaments bind together the talus, the os calcaneus, and other articulating bones and hold them in correct alignment.[1]

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[1]Arthur Steindler, Kinesiology of the Human Body (Springfield, Illinois: Charles C. Thomas, Publisher, 1955), pp. 373-382.

Primary movement in the ankle, dorsiflexion and plantar flexion, takes place in the tibio-talar joint. The muscles of dorsiflexion include the tibialis anterior, the peroneus tertius, and the exterior hallucis longus. Plantar flexion is accomplished mainly by contraction of the gastrocnemius, the soleus, and the plantaris. These three muscles insert at the posterior superior aspect of the os calcaneus by means of the Achilles tendon. Less important to plantar flexion are the tibialis posterior, the peroneus longus, and the flexor hallucis longus muscles.[1]

Mechanics of the Ankle

Propulsion for walking, running, or jumping comes from the force of extension of the lever systems representing the entire lower extremity.[2] According to Cooper and Glassow,[3] action of the knee extensors propels more than sixty per cent of the weight of the body with some contribution from metatarsal-phalangeal action. Actions of the hip and ankle joints function primarily in maintenance of direction. The metatarsal-phalangeal action is not due to muscles crossing these joints, but rather

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[1] Ibid., pp. 386-390.

[2] M. Gladys Scott, Analysis of Human Motion (New York: Meredith Publishing Company, 1963), p. 211.

[3] John M. Cooper and Ruth B. Glassow, Kinesiology (St. Louis: The C. V. Mosby Company, 1963), p. 142.

to the contraction of the ankle extensors and the forward momentum of the body.[1]

The combinations of actions at the ankle joint and the metatarsal-phalangeal joints forms a complicated lever system. Plantar flexion and dorsiflexion are not found in locomotion without action at the metatarsal-phalangeal joints. When the foot does not bear weight, plantar and dorsiflexion are examples of a first class lever system (Fig. 1). In plantar flexion the axis is

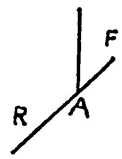

Fig. 1.--Diagramatic illustration of plantar flexion without weight on the foot, a first class lever system. The force arm (F) is the os calcaneus, the resistance arm (R) is the remainder of the foot, and the axis (A) is the tibio-talar joint.

the tibio-talar joint, the lever force arm is the os calcaneus, and the resistance arm is a combination of the remaining bones of the foot. In dorsiflexion the axis is the same, but the force and resistance arms are reversed.

During locomotion, this first class lever system is very transitory, and the action becomes that of a second class lever (Fig. 2, p. 6). The axis of this new system shifts to the metatarsal-phalangeal joints, and the force arm becomes the distance between the metatarsal heads and the posterior end of the os calcaneus. The resistance is

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[1]Ibid., p. 144.

created by the weight of the body falling just in front of the talus. Force for this movement is applied at the insertion of the Achilles tendon on the os calcaneus.[1]

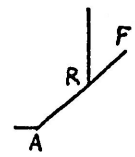

Fig. 2.--Diagramatic illustration of plantar flexion with body weight on the metatarsal heads, a second class lever system. The axis (A) is the metatarsal-phalangeal joints, the force arm (F) is the distance between the heads and the end of the os calcaneus, and the resistance (R) is the weight of the body in front of the talus.

According to the laws of mechanics, a second class lever is one of force and power. Lengthening the lever would increase the speed of the applied force delivered by the foot. By implication a longer os calcaneus should provide more potential speed in running and force in jumping than a shorter os calcaneus.

Statement of the Problem

This investigation entailed an anthropometric analysis of the os calcaneus of living, human subjects by means of an x-ray of the foot. Two hundred-sixty-four female and male students attending the Texas Woman's University and the North Texas State University were x-rayed during the academic year of 1967-1968.

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[1]M. Dena Gardner, The Principles of Exercise Therapy (New York: The Macmillan Company, 1963), p. 12.

Precise measurements of the os calcaneus and other pertinent anatomical structures were made from the x-ray negatives. A special technique was developed that involved the placement of a steel block of precise dimensions in the field of the x-ray beam. This technique insured accuracy of measurement. Measurements of the foot length and the calf girth were obtained on 169 of the subjects.

Upon the basis of the data thus compiled, the investigator has drawn conclusions concerning the relationships between the os calcaneus, the foot length, and the calf girth of American Negro and Caucasian subjects. The possible implications which such relationships may have for the mechanics of the ankle joint have been noted.

Purpose of the Study

The purpose of this investigation was to test the following hypotheses:

1. There is no significant difference between the mean overall length of the os calcaneus of the Negro subjects and that of the Caucasian subjects as measured from x-rays of the feet of the subjects.
2. There is no significant difference between the mean pivotal length of the os calcaneus of the Negro subjects and that of the Caucasian subjects as measured from x-rays of the feet of the subjects.
3. There is no significant difference between the mean thickness of the calcaneal pad of the Negro subjects

and that of the Caucasian subjects as measured from x-rays of the feet of the subjects.

4. There is no significant difference between the mean foot length of the Negro subjects and that of the Caucasian subjects.
5. There is no significant difference between the mean calf girth of the Negro subjects and that of the Caucasian subjects.
6. There is no significant correlation between the pivotal length of the os calcaneus and the calf girth for the Negro men.
7. There is no significant correlation between the pivotal length of the os calcaneus and the calf girth for the Caucasian men.
8. There is no significant correlation between the pivotal length of the os calcaneus and the calf girth for the Negro women.
9. There is no significant correlation between the pivotal length of the os calcaneus and the calf girth for the Caucasian women.
10. There is no significant correlation between the foot length and the calf girth for the Negro men.
11. There is no significant correlation between the foot length and the calf girth for the Caucasian men.
12. There is no significant correlation between the foot length and the calf girth for the Negro women.
13. There is no significant correlation between the foot length and the calf girth for the Caucasian women.

Definitions of Terms

The following definitions of terms were used throughout the study:

1. Overall Length of the Os Calcaneus: The overall length of the os calcaneus is the distance between the flattest portion of the os calcaneus at the junction of the calcaneus and the cuboid bones and the most posterior projection of the os calcaneus, as measured from the x-ray negative with a steel caliper to the nearest millimeter.
2. Pivotal Length of the Os Calcaneus: The pivotal length of the os calcaneus is the distance between the tip of the lateral process of the talus and the most posterior projection of the os calcaneus as measured from the x-ray negative with a steel caliper to the nearest millimeter.
3. Calcaneal Pad: The calcaneal pad, as defined for this study is the thinnest portion of tissue between the most posterior projection of the os calcaneus and the outer surface of the skin as measured from the x-ray negative with a steel caliper to the nearest millimeter.
4. Foot Length: The foot length is the distance between the tip of the longest toe and the most posterior projection of the heel as measured by a shoulder breadth caliper to the nearest millimeter, using minimum pressure on the skin surfaces. The distance

was a measure of the bare, weight-bearing left foot of each subject as he or she stood in a normal erect position.

5. Calf Girth: The calf girth is that external part of of the calf of greatest circumference as measured by a Gulick spring-loaded anthropometric tape to the nearest millimeter. The spring-loaded feature of the tape insures identical tension in the tape during the course of the measurement. The left calf of each subject was measured as he or she stood in a normal erect position.
6. Negro Subject: A Negro subject, as defined for this study was classified as such on the combined bases of hair type and color, facial features, and skin color.

Limitations of the Study

This investigation was subject to the following limitations:

1. The measurement of the x-ray negative of the left foot of 264 Negro and Caucasian males and females at the Texas Woman's University and the North Texas State University during the academic year of 1967-1968.
2. The measurement of the foot length and the calf girth of 169 of the above subjects.
3. The cooperation of the personnel of the Texas Woman's University Research Institute, Denton, Texas.
4. The accuracy of the measuring instruments.
5. The reliability of the measuring techniques.

Survey of Related Literature

The following review of the literature pertinent to this study is presented to describe the measuring techniques used by other investigators and to report the results that were obtained.

1. Amar reported the observations and research of Marey:

> . . . the calf of the negro is thin and has long fibers; that of the white man is fat, short, and prolonged by the long Achilles tendon. Now, in these two cases, the muscle must have the power to lift the weight of the man. Marey found that the calf muscle, being weaker in the negro, is attached to a longer lever, the salient of the os calcis (heel) being 40% further behind the axis of rotation than in the case of the European. This clever physiologist experimented by shortening the os calcis of a rabbit, and at the end of a year he saw the calf increase, that is to say, increased in strength to adapt itself to its function.[1]

2. Morehouse and Rasch referred to Amar's statements in the following manner:

> The length of the calcaneus may also be important in athletics. The longer the heel bone, the greater its mechanical advantage in enabling the jumper to utilize the power of the gastrocnemiussoleus group to propel himself upward. The efficiency of the calcaneus as a lever depends upon its ability to transmit the force of the muscle contraction to the "resistance" offered at the site of the contact of the foot with the ground. . . .
> . . . . . .
> Whether the Negro has a longer calcaneus, which would give greater leverage for

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[1]Marey, as cited by Amar, The Human Motor, p. 122.

running and jumping, is still a matter of dispute.[1]

3. In 1928, Hrdlička[2] completed an extensive anthropometric study of twenty-six full-blooded American Negro men and women. His measurements included the length of the left foot and the girth of the left calf, although no specific measuring techniques were given. The mean foot length for the twenty male subjects was 26.79 cm. with a mean of 36.90 cm. for the calf girth. The mean foot length of the six female subjects was 25.43 cm. No data were given for the calf girths of the female subjects.

4. Todd and Lindala[3] reported data gathered from cadevers and other sources. The measurement of the left foot of 269 subjects, both Caucasians and American Negroes, was included in the study; but the measuring techniques were not described. The mean foot length for the 100 Caucasian men was 24.38 cm.; for the 100 Negro men, 25.60 cm.; for the thirty-six Caucasian women, 21.48 cm.; and for the thirty-two Negro women, 23.11 cm.

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[1]Laurence E. Morehouse and Philip J. Rasch, Sports Medicine for Trainers, 2nd ed. (Philadelphia: W. B. Saunders Company, 1963), pp. 18, 20.

[2]Aleš Hrdlička, "The Full-Blooded American Negro," American Journal of Physical Anthropology, XII (July-September, 1928), 15-33.

[3]T. W. Todd and Anna Lindala, "Dimensions of the Body: White and American Negroes of Both Sexes," American Journal of Physical Anthropology, XII (July-September, 1928), 35-119.

5. Metheny[1] completed research on the bodily proportions of fifty-one American Negro males and a comparable number of Caucasian males, all of whom were students at the State University of Iowa. Among the measurements taken were calf girth, foot length, and "heel to sphyrion" length. Metheny reported that the mean "heel to sphyrion" length for the Negro men was 6.79 cm. In actuality, this distance is not feasible because "sphyrion" refers to the malleolus ear bone.[2] In all probability she intended "sphyrion" to mean one of the malleoli of the ankle joint. As it reads, however, this part of the report is incorrect.

The calf girth was obtained ". . . over the greatest bulge of the calf muscles, measured with a steel tape." The foot length was obtained in the following manner: ". . . foot prints are taken, toes, sides, and heel marked with pencil, the measurement made from the print, using millimeter ruler." The method for obtaining the position of the "sphyrion" was not given in the report.

Metheny found that the mean foot length of the Negro subjects exceeded that of the Caucasian

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[1]Eleanor Metheny, "Some Differences in Bodily Proportions Between American Negro and White Male College Students as Related to Athletic Performance," Research Quarterly, X (December, 1939), 41-53.

[2]L. C. R. Agnew, ed., Dorland's Illustrated Medical Dictionary, 24th ed. (Philadelphia: W. B. Saunders Company, 1965), p. 1447.

subjects significantly (C.R.=2.86); the same was true for the calf girth (C.R.=3.07). The ratio of "heel to sphyrion" length to foot length in the Negro subjects also significantly exceeded that of the Caucasian subjects (C.R.=3.72).

6. Bernstein[1] reported a survey conducted by track coach Harry W. Campbell at Los Angeles City College, California. The subjects were Negro and Caucasian track men and non-athletes. The numbers comprising the groups were not given. The measurements included foot length and heel-to-ankle length, but no measuring techniques were described.

The mean heel-to-ankle measurement was 2.75 inches (6.98 cm.) for the Negro athletes, 2.60 inches (6.60 cm.) for the Caucasian athletes, and 2.40 inches (5.85 cm.) for the non-athletes. The mean foot length of the Negro athletes was 10.8 inches (27.43 cm.), whereas that of the Caucasian athletes was 10.6 inches (26.92 cm.), and of the non-athletes, 10.4 inches (26.41 cm.). Although no statistical treatment of the data was reported, Bernstein concluded ". . . that it is probably this physical asset[longer heel-to-ankle length] that makes the negro a superior track man."

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[1]R. L. Bernstein, "Their Best Foot Foreward," Athletic Journal, XXII (April, 1942), 22.

7. Steggerda[1] measured 100 Negro males at Tuskegee Institute, Alabama, in 1942. His report included the mean calf girth and the mean foot length, which were 36.23 cm. and 27.42 cm., respectively.

8. In 1946, Freedman, et al., [2] completed a study of 6,774 men in the United States Army, of which 5.574 were Caucasian men and 1,200 were Negro men. The purpose of the study was to secure information concerning the dimensions of the feet of soldiers relative to the manufacture of shoes for the Army. Among the twenty-seven measurements obtained were the foot length and the indentation of the Achilles tendon above the os calcaneus, the latter also called the posterior heel contour. All measuring techniques were performed by technicians trained specifically for the study. The measurements were of the right foot with each subject standing in normal erect position with the weight evenly distributed between both feet.

The foot length was a measure of the distance between the tip of the longest toe and the posterior aspect of the heel. The mean foot length for the Caucasian men was 26.84 cm.; for the Negro men it

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[1]M. Steggerda, "Bodily Measurements on 100 Negro Males from Tuskegee Institute," Research Quarterly, XIII (October, 1942), 275-279.

[2]Arthur Freedman, et al., Foot Dimensions of Soldiers (Fort Knox, Kentucky: Armored Medical Research Laboratory, 1946), pp. i, 10-40.

was 27.55 cm. The posterior heel contour was: "contour of the posterior aspect to the heel and lower leg in the mid-sagittal plane, to a height of 72 mm. (2 4/5 in.) above the ground." Overall, the posterior heel contour of the Negroes and Caucasians was approximately the same shape, but the Negro men had ". . . the more marked anterior indentation of the curvature superior to the os calcis. . ." (See Fig. 5, p. 36).

9. Della[1] completed a study of forty-seven male high school athletes, none of whom was considered to have outstanding athletic ability. The study was concerned with relationships between several foot measurements and jumping performance. Included in the foot measurements were total foot length and heel-to-ankle length. To obtain these measurements a device was used that provided constant pressure on the posterior heel in an attempt to eliminate the error caused by the calcaneal pad.

The heel-to-ankle length was obtained by measuring from both the lateral and medial malleoli of the ankle to the flattened portion of the heel. The total foot length was the distance between the longest toe and the flattened portion of the heel. The average of measurements of both feet was used in

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[1]Dan G. Della, "Individual Differences in Foot Leverage in Relation to Jumping Performance," Research Quarterly, XXI (March, 1950), 11-19.

the computations. Jumping performance was measured by the Sargent vertical jump, the running high jump, and the standing broad jump.

On the basis of correlation coefficients computed for the several variables, Della concluded that the total foot length was not related to jumping ability (r=0.02). He concluded that the smaller the heel-to-ankle length, the less the advantage in the performance of the Sargent vertical jump (r=0.33); and that the heel-to-ankle distance correlated negatively, but not significantly, with the running high jump (r=-0.15). The standing broad jump also correlated negatively with the heel-to-ankle length (r=-0.20).

CHAPTER II

PROCEDURES FOLLOWED IN THE DEVELOPMENT OF THE STUDY

This chapter will encompass the development of this study under the following major headings: Sources of Data, Preliminary Procedures, Method for Obtaining Subjects, Equipment and Personnel for Obtaining X-rays, Special Equipment for Obtaining X-rays, Procedures for Taking X-rays, Procedures for Measurement of the X-rays, Procedures for the Selected Anthropometric Measurements, Statistical Analysis of the Data, Preparation of the Written Report, and Summary.

Sources of Data

The sources of data for the development of this investigation included both documentary and human sources. The documentary sources were books, periodicals, and mimeographed materials related to all aspects of the study, as well as pertinent theses and dissertations. The human sources were 264 undergraduate students attending the Texas Woman's University and the North Texas State University in Denton, Texas, during the academic year of 1967-1968.

Preliminary Procedures

The investigator outlined and adhered to several preliminary procedures, the first of which was a review of the literature pertinent to the study. The review included the techniques used by other investigators to measure the heel, foot, and calf; the results obtained by these investigators; and mechanical and kinesiological principles involving the foot and ankle.

Through the cooperation of the Texas Woman's University Research Institute and Professor George Vose, arrangements were made for the use of an x-ray unit and x-ray film. The services of licensed x-ray technicians and laboratory personnel to develop the x-ray negatives were also secured.

A tentative outline of the study was prepared and presented on March 21, 1968, in a Graduate Seminar of the College of Health, Physical Education, and Recreation at the Texas Woman's University. On the basis of suggestions and recommendations which accrued from the seminar, the outline was revised and approved by the members of the thesis committee. The approved prospectus was then filed in the office of the Dean of Graduate Studies at the Texas Woman's University.

Method for Obtaining Subjects

Volunteers for this study were secured among the undergraduate students of the Texas Woman's University and the North Texas State University. The initial participants

were helpful in the recruitment of more subjects. In all, 264 subjects participated in the study, of which 10 were Negro men, 29 were Caucasian men, 39 were Negro women, and 189 were Caucasian women.

Equipment and Personnel for Obtaining X-rays

X-ray photographs of the ankle and/or foot were obtained through the cooperation of Professor George Vose and the Texas Woman's University Research Institute. The x-ray film was Eastman Kodak AA film, either 8 inches by 11 inches or 11 inches by 14 inches, held in cardboard film holders. The instrument used was a General Electric Imperial Diagnostic X-ray Unit, equipped with a generator model GE KX-8 and an X-ray Tube model GE HRT-2. The dosage for each x-ray exposure was 167±2 milli-roetgens. This dosage was one which Professor Vose has established through prior research as ideal for x-ray of the os calcaneus for bone densitometric studies.[1] Licensed x-ray technicians, who have had several years of experience with work in bone densitometry, prepared the films. The technicians had advance knowledge of the nature of the project and the type of x-ray negative required. The x-ray negatives were developed by experienced laboratory technicians in the employ of the Research Institute.

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[1]Pauline Beery Mack, et al., "Bone Demineralization of Foot and Hand of Gemini-Titan IV, V and VII Astronauts During Orbital Flight," The American Journal of Roentgenology, Radium Therapy and Nuclear Medicine, C (July, 1967), 503-511.

Special Equipment for Obtaining X-rays

It is known that there is a possibility of magnification of the projected image on an x-ray film. The amount of magnification incurred depends upon the distance between the x-ray source and the object being x-rayed and any angular changes of the beam. The distance, in turn, depends upon the area to be pin-pointed by the beam.[1]

Knowledge of the degree of magnification was absolutely essential in the present study. To determine whether or not magnification errors were present in the finished film, a reference object was included in the field of the x-ray beam. The reference object took the form of a steel block placed on the film holder in the same plane as the os calcaneus. The steel block was machined with micrometer precision to the dimensions of 1.0 ± 0.005 inch by 0.5 ± 0.005 inch (2.54 ± 0.013 cm. by 1.27 ± 0.013 cm.).

Procedures for Taking X-rays

Each subject was requested to lie comfortably on his left side on the x-ray table with the left foot lying atop the film holder. The foot was then positioned further by the technicians in order that the angle between the anterior portion of the lower leg and the superior portion of the foot approximated ninety degrees. The

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[1]Richard V. Ganslen, "Cinematographical Analysis Techniques Today," Denton, Texas, 1969, pp. 1-2 (Mimeographed.)

steel block was then placed in position on the film holder (Fig. 3). The remainder of the body of the subject was covered by lead sheets, and the x-ray film was exposed.

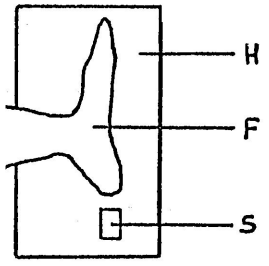

Fig. 3.--Top view of the position of the foot (F) and the steel block (S) on the film holder (H).

The angle of the foreleg relative to the foot involved in the positioning of the foot was not critical. This fact had been determined previously by measuring the required dimensions of the os calcaneus from x-rays of the feet of two subjects with the foot of each subject held in plantar flexion, in normal position (approximately ninety degrees), and in dorsiflexion. Virtually no change in the dimensions was encountered.

Procedures for Measurement of the X-rays

The overall length of the os calcaneus, the pivotal length of the os calcaneus, and the calcaneal pad (Fig. 4) were measured from x-ray negatives according to the techniques described on page nine in Chapter I. To insure accuracy, the image of the steel block was also measured with the steel caliper for each x-ray negative as it was examined.

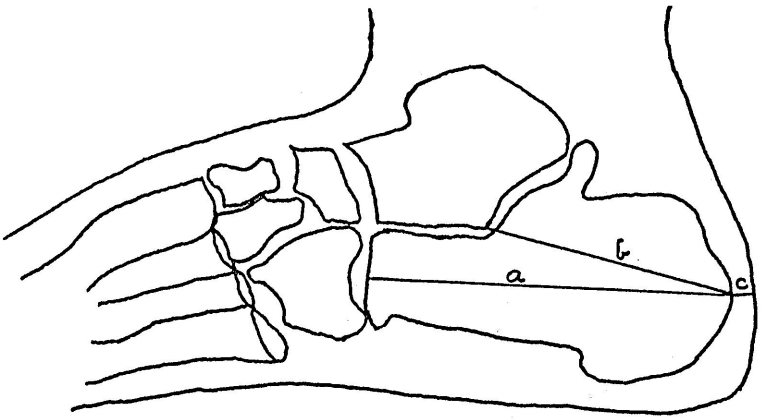

Fig. 4.--Diagramatic illustration of the overall length of the os calcaneus (a), the pivotal length of the os calcaneus (b), and the calcaneal pad (c).

Procedures for Selected Anthropometric Measurements

The foot length and the calf girth were measured on 169 of the 264 subjects who were x-rayed. The measuring techniques, described on pages nine and ten in Chapter I, in most cases were applied a few minutes prior to the actual x-ray procedures. Only 169 of the subjects were included in this part of the study because obtaining the foot length and the calf girth was not in the original research design. Approximately 100 subjects had been x-rayed before these measurements were incorporated into the study.

Fifty of the subjects from whom the selected anthropometric data were obtained were remeasured two days after the original measurements were completed. These data were necessary in order to test the reliability

of the measuring techniques by the test-retest correlation method.

Statistical Analysis of the Data

The measurement data for all subjects were tabulated into four groups: Negro men, Caucasian men, Negro women, and Caucasian women. The mean and standard deviation were then calculated for each measurement within its respective group.

The Duncan Multiple Range Test[1] was developed to simplify the determination of significance of the difference among the means of three or more groups. For this study the Duncan Multiple Range Test was applied to five separate sets of data to test the hypotheses concerning the difference among the means of the various anatomical dimensions. For example, the means of the pivotal length of the os calcaneus of the Negro men, the Caucasian men, the Negro women, and the Caucasian women were compared as one set of data. In a like manner the means of the overall length of the os calcaneus, the means of the thickness of the calcaneal pad, the means of the foot length, and the means of the calf girth were examined.

The data compiled for the foot length and the calf girth were matched with the data for the pivotal length of the os calcaneus for each of the 169 subjects.

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[1]F. J. McGuigan, Experimental Psychology (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1960), pp. 172-187.

The pivotal length was correlated with the calf girth for each of the four groups of subjects utilizing an Olivetti-Underwood Programma 101 Computer, which was programmed to compute Pearson Product-Moment correlation coefficients. The pivotal length of the os calcaneus was chosen for correlation rather than the overall length because this length is thought to be a critical factor from a mechanical viewpoint when the force applied by the calf muscles is effected on the os calcaneus.

The Olivetti-Underwood Programma 101 Computer was utilized to correlate the data on the foot length with those on the calf girth for each of the four groups of subjects. It was employed also to correlate the test-retest data and to obtain the t-test of the hypothesis of zero order correlation for each of the correlation coefficients.

Procedures for Preparation of the Written Report

Upon completion of the presentation, analysis, and interpretation of the data collected, the investigator summerized the report, drew conclusions with respect to the dimensions of the os calcaneus and the interrelationships between the calf girth and the foot length and the pivotal length of the os calcaneus. In addition, implications for the mechanics of ankle joint movement derived from the data were noted. The investigator made recommendations for further studies and developed a bibliography and an appendix.

Summary

In this chapter the procedures followed in the course of this study have been described. Information concerning the source of the subjects and the technical procedures used in x-raying the foot have been discussed. The procedures for measuring the overall length of the os calcaneus, the pivotal length of the os calcaneus, and the thickness of the calcaneal pad have been described in detail. Procedures have been outlined for statistical analysis of the data and for the development of a written report of the study.

CHAPTER III

ANALYSIS AND INTERPRETATION OF FINDINGS

Tabulation of the Data

The measurements from the x-ray negatives and the selected anthropometric measurements were tabulated into four groups: Negro men, Caucasian men, Negro women, and Caucasian women. The raw data for these classifications may be found in Appendix A (p. 49). The means and standard deviations for the data obtained from the 264 x-ray negatives are depicted in Table 1 (p. 28). The means and standard deviations for the selected anthropometric measurements secured from 169 of the subjects are listed in Table 2 (p. 28).

It is apparent in Tables 1 and 2 that the standard deviations for each measurement vary only a few hundredths of a centimeter among the four groups. This finding indicates that the variability of any given measurement among the four groups of subjects is quite small.[1] Noteworthy is the fact that if the tables were read from left to right instead of top to bottom, the sizes of the

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[1]Robert H. Koenker, Simplified Statistics (Bloomington, Illinois: McKnight & McKnight Publishing Company, 1961), p. 9.

TABLE 1

MEANS AND STANDARD DEVIATIONS OBTAINED BY MEASUREMENT OF THE X-RAY NEGATIVES (N=264)

	Negro Men (N=10)	Caucasian Men (N=29)	Negro Women (N=39)	Caucasian Women (N=189)
Overall Length, Os Calcaneus	8.51±0.51 cm.	8.28±0.51 cm.	7.71±0.44 cm.	7.40±0.44 cm.
Pivotal Length, Os Calcaneus	7.05±0.45 cm.	6.49±0.55 cm.	6.17±0.40 cm.	5.88±0.38 cm.
Calcaneal Pad	1.34±0.22 cm.	1.02±0.15 cm.	1.12±0.22 cm.	0.92±0.17 cm.

TABLE 2

MEANS AND STANDARD DEVIATIONS OF THE SELECTED ANTHROPOMETRIC MEASUREMENTS (N=169)

	Negro Men (N=6)	Caucasian Men (N=22)	Negro Women (N=32)	Caucasian Women (N=109)
Foot Length	27.72±0.62 cm.	26.76±1.38 cm.	24.97±1.06 cm.	23.86±1.28 cm.
Calf Girth	40.60±2.23 cm.	37.67±2.84 cm.	34.45±3.14 cm.	34.30±2.76 cm.

dimensions decrease. Thus, the measurements for the Negro men exceed those of the Caucasian men, and the dimensions for the Negro women are greater than those of the Caucasian women. None of these dimensional differences, however, is statistically significant.

Results of the Duncan Multiple Range Test

The Duncan Multiple Range Test was applied to five sets of means, a set being comprised of the four mean measurements for each dimension. These results of these five tests are illustrated in Tables 3 and 4 (p. 30).

For any given measurement the Negro subject, male or female, has larger dimensions than his or her Caucasian counterpart. In other words, the means for all of the measurements of the Negro subjects exceed the means for the Caucasian subjects, but the differences are not statistically significant. Comparison of any combination of the four groups indicates that there is no significant difference in the overall length of the os calcaneus, the pivotal length of the os calcaneus, the thickness of the calcaneal pad, the foot length, or the calf girth.

Interrelationships of Selected Dimensions

The data for the pivotal length of the os calcaneus were matched with corresponding calf girths for the 169 subjects for whom the latter measurement was available. Pearson Product-Moment correlation coefficients

TABLE 3

DUNCAN MULTIPLE RANGE TESTS APPLIED TO THE CALCANEAL DIMENSIONS OF THE FOUR GROUPS OF SUBJECTS (N=264)

	Negro Men (N=10)	Caucasian Men (N=29)	Negro Women (N=39)	Caucasian Women (N=189)	
Overall Length, Os Calcaneus	8.51 cm.	8.28 cm.	7.71 cm.	7.40 cm.	a
Pivotal Length, Os Calcaneus	7.05 cm.	6.94 cm.	6.17 cm.	5.88 cm.	a
Calcaneal Pad	1.34 cm.	1.02 cm.	1.12 cm.	0.92 cm.	a

[a]Underlined values do not differ at $P < 0.05$ level of probability.

TABLE 4

DUNCAN MULTIPLE RANGE TESTS APPLIED TO THE SELECTED ANTHROPOMETRIC MEASUREMENTS OF THE FOUR GROUPS OF SUBJECTS (N=169)

	Negro Men (N=6)	Caucasian Men (N=22)	Negro Women (N=32)	Caucasian Women (N=109)	
Foot Length	27.72 cm.	26.76 cm.	24.97 cm.	23.86 cm.	a
Calf Girth	40.60 cm.	37.67 cm.	34.45 cm.	34.30 cm.	a

[a]Underlined values do not differ at the $P < 0.05$ level of probability.

were calculated for these two measurements with an Olivetti-Underwood Programma 101 Computer. In a like manner the foot lengths of these subjects were matched with their calf girths, and correlation coefficients were computed. The resulting coefficients for the male subjects are shown in Table 5; coefficients for the female subjects may be found in Table 6 (p. 32). These tables also present the t-test of the hypothesis of zero order correlation and the value of t in terms of the probability of a chance occurrence of the coefficient.

The most obvious observation about these tables is that all of the coefficients are positive. The findings of this study indicate that the longer the pivotal length of the os calcaneus, the larger the calf girth. Also notable is the fact that all but three of the coefficients are significant at the 0.05 level of probability or better.

TABLE 5

CORRELATION OF THE PIVOTAL LENGTH OF THE OS CALCANEUS WITH THE CALF GIRTH AND THE FOOT LENGTH WITH THE CALF GIRTH FOR THE NEGRO MEN AND THE CAUCASIAN MEN

	Negro Men (N=6)			Caucasian Men (N=22)		
	r	t*	P	r	t**	P
Pivotal Length-Calf Girth	0.39	0.8501	>0.05	0.48	2.4775	<0.05
Foot Length-Calf Girth	0.74	2.2230	>0.05	0.58	3.2141	<0.01

*To be significant at the 0.05 level of probability with d.f.+4, t must $\geq$ 2.776.

**To be significant at the 0.05 level of probability with d.f.=20, t must $\geq$ 2.086; for the 0.01 level, t $\geq$ 2.845.

TABLE 6

CORRELATION OF THE PIVOTAL LENGTH OF THE OS CALCANEUS WITH THE CALF GIRTH AND THE FOOT LENGTH WITH THE CALF GIRTH FOR THE NEGRO WOMEN AND THE CAUCASIAN WOMEN

	Negro Women (N=32)			Caucasian Women (N=109)		
	r	t*	P	r	t**	P
Pivotal Length-Calf Girth	0.39	2.3015	<0.05	0.42	4.8413	<0.001
Foot Length-Calf Girth	0.31	1.7864	>0.05	0.37	4.1600	<0.001

*To be significant at the 0.05 level of probability with d.f.=30, t must $\geq$ 2.042.

**To be significant at the 0.001 level of probability with d.f.=107, t must $\geq$ 3.330.

The coefficients are low, however; and according to Koenker[1] correlation coefficients ranging from 0.20 to 0.59 show only a slight to fair degree of relationship, despite the demonstration of significance. In fact, the coefficients for the Negro men (N=6) and the Caucasian men (N=22) are subject to doubtful interpretation simply because of the size of the sample. Doubtful interpretation will usually be encountered with any correlation calculated for less than thirty cases.[2]

The sample sizes of the Negro women (N=32) and the Caucasian women (N=109) are of adequate numbers, permitting some inferences to be made. The first, of course, is that the relationship between the pivotal length of the os calcaneus and the calf girth is positive:

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[1]Koenker, Simplified Statistics, p. 52.

[2]Ibid., p. 54.

as one dimension increases or decreases in size, the other will do likewise. Secondly, the coefficients for both pairs are slightly higher for the Caucasian women than for the Negro women. This difference could be attributable to sample size or to some yet unknown factor. The size of the calf girth is related to body weight. This factor has been explored by Pruitt,[1] who found a correlation coefficient of r=0.75 between the calf girth and the weight of the subject. Thirdly, there appears to be a slightly more dependable relationship between the pivotal length and the calf girth for both groups of women than between the foot length and the calf girth. The opposite seems to be true for the male subjects. Although only a trend can be noted, the more dependable relationship for both groups of male subjects is that between the foot length and the calf girth rather than between the pivotal length and the calf girth.

Reliability of the Measuring Techniques

Ideally, to ascertain the reliability of the measurements obtained from the x-ray negatives, at least thirty of the subjects should have been x-rayed a second time and the calcaneal dimensions measured on the second set of negatives. This procedure would have

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[1]Marilyn Joyce Pruitt, "Anthropometric Survey of College Women with Reference to Teaching Physical Education Skills and Design of Athletic Equipment" (unpublished Ph.D. dissertation, Texas Woman's University, Denton, Texas, August, 1968), p. 43.

been essentially a re-test of the x-ray methods in producing a similar or identical image of the required area of the foot. Because a second x-raying of the subjects was not feasible, accuracy of the projected image was determined by comparing the image of the steel block on each negative with its actual known length of 2.54±0.013 cm. In every case the length of the image was 2.6 cm.; therefore, the dimensions were highly accurate.

Remeasurement of the foot length and the calf girth was carried out two days after the original measurements had been completed. The first and second sets of data for the foot length and the calf girth were correlated using the Olivetti-Underwood Programma 101 Computer. The results of this test-retest procedure, yielding a reliability coefficient, are illustrated in Table 7.

TABLE 7

CORRELATION OF THE TEST-RETEST DATA FOR THE FOOT LENGTH AND THE CALF GIRTH (N=50)

	r	t*	P
Foot Length	0.986	40.6268	<0.001
Calf Girth	0.988	40.4814	<0.001

*To be significant at the 0.001 level of probability with d.f.=48, t must ≥ 3.525.

The reliability coefficients in both cases exceed r=0.98, and both are significant at better than the 0.001

level of probability. The techniques give highly reliable results.

Interpretation of the Statistical Data

A major observation of Marey[1] was that the salient of the os calcaneus (comparable to the pivotal length of the os calcaneus in this investigation) was forty per cent longer in the Negro than in the Caucasian. The results of this study have shown clearly that the mean pivotal length of the os calcaneus of the Negro male is but 8.6 per cent longer (a mean difference of 0.1 cm.) than that of the Caucasian male. Comparative visual examination from an external viewpoint of the foot of a Negro subject and the foot of a Caucasian subject might lead one to suppose that the os calcaneus of the Negro subject is the longer of the two. Such an observational conclusion is due primarily to the differences in the configuration of the foot. Freedman[2] has shown that the Negro possesses a more pronounced indentation in the region above the os calcaneus than the Caucasian. Variations in heel contour are depicted in Fig. 5, p. 36. In all probability this fact led Marey[3] to his overestimate of the difference in the length of the os calcaneus.

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[1]Marey, as cited by Amar, The Human Motor, p. 122.

[2]Freedman, Foot Dimensions of Soldiers, pp. 130-133.

[3]Marey, as cited by Amar, The Human Motor, p. 122.

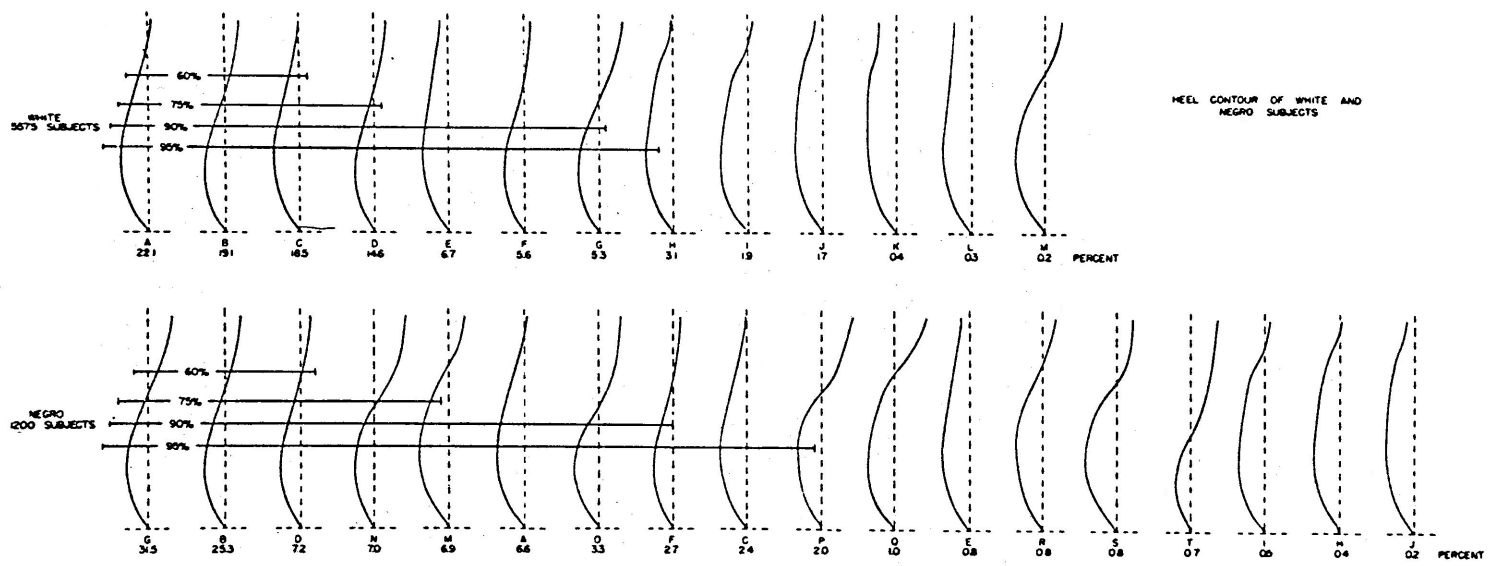

Figure 97

Fig. 5.--Illustration of the posterior heel contour of Negro and Caucasian males. Percentages shown apply to the population studied. From: Freedman, Foot Dimensions of Soldiers, p. 131.

Theoretically an individual with a longer pivotal length of the os calcaneus should have a mechanical advantage in running and jumping. If Negro athletes were distinctly superior to Caucasian athletes, the calcaneal advantage would manifest itself. Since it has not, other contributing factors must be given consideration. Such factors might be the crural index, training and performing techniques, or simply motivation for success.

The data on the foot length and the calf girth accrued during this investigation were compared with data on these dimensions reported by Hrdlicka,[1] Todd and Lindala,[2] Bernstein,[3] Steggerda,[4] and Freedman[5]. In all cases the means of the foot length and the means of the calf girth found in the present study exceed those reported in the above studies. No statistical procedures were carried out, however, to ascertain if the differences in the measurements reported by the authorities listed were significant. Since the cited studies were conducted some twenty years ago, the differences might have a nutritional basis. They could be attributed also to variance in geographical area or even statistical error.

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[1]Hrdlička, "The Full-Blooded American Negro," p. 30.

[2]Todd and Lindala, "Dimensions of the Body," p. 103.

[3]Bernstein, "Their Best Foot Foreward," p. 22.

[4]Steggerda, "Bodily Dimensions," p. 277.

[5]Freedman, Foot Dimensions of Soldiers, p. 40.

The examination of the interrelationships between the pivotal length of the os calcaneus and the calf girth and between the foot length and the calf girth evolved from a critical inspection of the original research of Marey.[1] Marey postulated that the larger calf of the Caucasian man indicated a shorter os calcaneus. In other words, Marey postulated an inverse or negative relationship between the length of the os calcaneus and the calf girth; i.e., as the length of the os calcaneus increases, the calf girth decreases. He supported his hypothesis by surgically shortening the posterior end of the os calcaneus of one rabbit. In the course of a year he observed hypertrophy of the calf muscles of the rabbit.

A critical examination of the data of this investigation has shown that the relationship between the pivotal length of the os calcaneus and the calf girth is positive, thus refuting Marey's hypothesis.

Summary

This chapter was devoted to an analysis and interpretation of the data. The dimensions were tabulated into four groups: Negro men, Caucasian men, Negro women, and Caucasian women. In all cases the mean dimensions of the Negro subjects exceeded those of the Caucasian subjects. None of the dimensional differences was statistically significant. The resulting interpretation

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[1]Marey, as cited by Amar, The Human Motor, p. 122.

was that the Negro man or woman does not have the mechanical advantage of a longer os calcaneus. All of the correlation coefficients were positive; and all but three were significant at the 0.05 level of probability or better. The coefficients were low, indicating at best a fair degree of relationship between either the pivotal length or the foot length and the calf girth. The techniques for measuring the foot length and the calf girth were reliable at the 0.001 level of probability. The length of the image of the steel block was 2.6 cm. for every x-ray negative, insuring a high degree of accuracy of calcaneal measurement.

CHAPTER IV

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS FOR FURTHER STUDIES

Statement of the Problem

This investigation entailed an anthropometric analysis of the os calcaneus of living, human subjects by means of an x-ray of the ankle and/or foot. The subjects, 264 in number, were male and female students attending the Texas Woman's University and the North Texas State University, in Denton, Texas, during the academic year of 1967-1968.

Precise measurements of the os calcaneus and other pertinent anatomical structures were made from x-ray negatives. A special technique was developed that involved the inclusion of a steel block of rigidly exact dimensions in the field of the x-ray beam in the plane of the os calcaneus. This technique insured extreme accuracy of the measurements of the finished x-ray negatives. Measurements of the foot length and the calf girth were obtained on 169 of the subjects.

Purpose of the Study

The purpose of this investigation was to test the following hypotheses:

1. There is no significant difference between the mean overall length of the os calcaneus of the Negro subjects and that of the Caucasian subjects as measured from x-rays of the feet of the subjects.
2. There is no significant difference between the mean pivotal length of the os calcaneus of the Negro subjects and that of the Caucasian subjects as measured from x-rays of the feet of the subjects.
3. There is no significant difference between the mean thickness of the calcaneal pad of the Negro subjects and that of the Caucasian subjects as measured from x-rays of the feet of the subjects.
4. There is no significant difference between the mean foot length of the Negro subjects and that of the Caucasian subjects.
5. There is no significant difference between the mean calf girth of the Negro subjects and that of the Caucasian subjects.
6. There is no significant correlation between the pivotal length of the os calcaneus and the calf girth for the Negro men.
7. There is no significant correlation between the pivotal length of the os calcaneus and the calf girth for the Caucasian men.

8. There is no significant correlation between the pivotal length of the os calcaneus and the calf girth for the Negro women.
9. There is no significant correlation between the pivotal length of the os calcaneus and the calf girth for the Caucasian women.
10. There is no significant correlation between the foot length and the calf girth for the Negro men.
11. There is no significant correlation between the foot length and the calf girth for the Caucasian men.
12. There is no significant correlation between the foot length and the calf girth for the Negro women.
13. There is no significant correlation between the foot length and the calf girth for the Caucasian women.

Procedures

The left ankle and/or foot of each of the 264 subjects was x-rayed with a precisely measured steel block included in the field of the x-ray beam. The pivotal length of the os calcaneus, the overall length of the os calcaneus, and the thickness of the calcaneal pad were measured from the original x-ray negatives. The image of the steel block was also measured from each negative in order to ascertain possible projection errors. The foot length and the calf girth were measured on 169

of the subjects. These data were tabulated into four groups: Negro men, Caucasian men, Negro women, and Caucasian women. The mean and standard deviation were calculated for each measurement within its respective group, yielding five sets of data. The five sets of data were separately analyzed through the use of the Duncan Multiple Range Test. For example, the means of the pivotal length of the os calcaneus of the Negro men, the Caucasian men, the Negro women, and the Caucasian women were compared as one set of data. In a like manner, the means of the other dimensions were examined.

The foot length and the calf girth of each of the 169 subjects were matched with the corresponding pivotal length of the os calcaneus. The correlation between the pivotal length and the calf girth was determined as well as the correlation between the foot length, utilizing an Olivetti-Underwood Programma 101 Computer programed to compute Pearson Product-Moment correlation coefficients.

The foot length and the calf girth on fifty subjects were remeasured two days after the original measurements were completed. The correlation between these two sets of data was determined with the computer to obtain a reliability coefficient. The computer also calculated the t-test to determine the significance of the correlation for this coefficient as well as for the other coefficients.

Results

Because the standard deviations for any given measurement vary only a few hundredths of a centimeter, the variability for a given measurement among the four groups is quite small. Although overall the dimensions of the Negro subjects exceed those of the Caucasian subjects, there is no statistically significant difference among the means of the overall length of the os calcaneus, the means of the pivotal length of the os calcaneus, the means of the thickness of the calcaneal pad, the means of the foot length, or the means of the calf girth. Because the level of significance achieved in these tests was greater than the 0.05 level of probability, the first five hypotheses stated on page 41 are accepted.

There is a significant, low, positive correlation between the pivotal length of the os calcaneus and the calf girth for the Caucasian men ($r=0.48$, $P=0.05$), the Negro women ($r=0.39$, $P=0.05$), and the Caucasian women ($r=0.42$, $P=0.001$). Hypotheses 7, 8, and 9 are not accepted, therefore. Hypotheses 11 and 13 are not accepted also because a significant positive correlation between the foot length and the calf girth was found for the Caucasian men ($r=0.58$, $P=0.01$) and the Caucasian women ($r=0.37$, $P=0.001$). The correlation of pivotal length and calf girth for the Negro men is not significant ($r=0.39$, $P > 0.05$); the same is true for the correlation of the foot length and the calf girth for

this group ($r=0.74$, $P > 0.05$). The correlation of the foot length and the calf girth for the Negro women is not significant also ($r=0.31$, $P > 0.05$). On these bases, hypotheses 6, 10, and 12 are not accepted. Even the highest of the coefficients ($r=0.58$) indicates, at best, a fair degree of relationship. Correlation coefficients for the test-retest measurements for the foot length ($r=0.98$) and the calf girth ($r=0.98$) are significant at the 0.001 level of probability, indicating an extremely high degree of reliability for these measuring techniques. The degree of magnification in the finished x-ray negatives was judged negligible because the length of the image of the steel block was 2.6 cm. for every negative, as compared with an actual length of 2.54 ± 0.013 cm.

Conclusions

Based upon analysis and interpretation of the results, the investigator has reached the following conclusions:

1. Skeletal x-ray is a most useful, accurate tool for the science of anthropometry.
2. The techniques used in this study for measuring the foot length and the calf girth are highly reliable and introduce precision never heretofore available.
3. Persons of Negro descent have slightly longer calcaneal dimensions than Caucasian persons, but these dimensional differences are not statistically significant.

4. The mechanical advantage which has been attributed to Negro persons over Caucasian persons in running and jumping cannot be ascribed to a longer calcaneal dimension.
5. On the average Negro subjects have longer feet and larger calf circumferences than Caucasian subjects, but the differences are not statistically significant.
6. External measurement of the heel from either of the malleoli of the ankle to its posterior aspect to ascertain the pivotal length of the os calcaneus will result in gross errors because of the presence of the calcaneal pad. This error will range from 0.6 cm. to 1.8 cm. and will average at least 1.0 cm.
7. The foot length apparently has a more direct influence on the size of the calf girth than does the pivotal length of the os calcaneus.

Recommendations for Further Studies

Analysis and interpretation of the findings of this study, as well as an analysis of the literature pertaining to this study, suggests the desirability for a number of additional studies. The following are recommendations for further studies:

1. A study to determine the intercorrelations among the pivotal length of the os calcaneus, the weight, and the calf girth of the subjects.
2. A study to determine the correlation between the pivotal length of the os calcaneus and running and/or jumping ability.

3. A study by x-ray techniques to determine the ball length of the foot, the ball length being defined as that distance between the heads of the metatarsals and the posterior aspect of the os calcaneus.
4. A study to determine the correlation of the ball length of the foot with running and/or jumping ability.
5. A study to compare x-rays of the os calcaneus of the top twenty-seven per cent in achievement level and the bottom twenty-seven per cent in achievement level of selected athletic groups.
6. A study to compare x-rays of the os calcaneus of champion performers, both Negro and Caucasian, in track, football, and basketball.

APPENDIX A

RAW DATA

RAW DATA

Raw Data for the Negro Men

X-ray Number	Pivotal Length	Overall Length	Calcaneal Pad	Foot Length	Calf Girth
61	7.0 cm.	8.5 cm.	1.2 cm.	27.8 cm.	40.0 cm.
62	6.4	7.7	1.8	26.9	38.7
117	8.0	9.7	1.2	--	--
118	7.0	8.5	1.2	--	--
119	6.9	8.7	1.2	--	--
131	7.4	8.4	1.3	--	--
205	6.9	8.3	1.1	27.8	40.7
206	6.8	8.3	1.6	28.1	44.7
208	6.7	8.2	1.4	27.0	37.8
209	7.4	8.8	1.4	28.7	41.7

Raw Data for the Caucasian Men

X-ray Number	Pivotal Length	Overall Length	Calcaneal Pad	Foot Length	Calf Girth
46	7.1 cm.	8.7 cm.	0.9 cm.	26.5 cm.	38.6 cm.
47	7.9	8.5	1.0	26.4	36.5
48	7.5	9.0	1.4	--	--
49	7.2	9.1	1.1	28.3	40.6
50	7.3	9.1	1.0	28.2	41.6
52	7.0	8.8	1.0	--	--
53	6.8	8.6	0.9	26.7	40.2
55	6.5	8.5	0.9	27.0	35.0
57	6.7	8.2	1.0	25.7	38.4
60	7.7	9.0	1.2	--	--
63	7.1	8.7	1.2	29.4	38.4
64	7.9	9.2	1.0	--	--
65	6.8	8.6	1.1	27.3	43.0
66	7.7	9.1	1.1	27.6	37.9
113	6.6	8.4	0.8	26.7	33.5
114	6.0	7.7	1.0	23.7	34.2
115	7.2	8.9	1.0	--	--
116	6.1	7.4	1.2	25.2	34.6
120	6.5	8.0	0.8	24.6	37.0
121	7.2	9.0	0.8	27.6	37.2
122	6.4	8.1	1.1	--	--
123	6.6	8.2	1.0	--	--
124	7.2	9.1	0.9	27.9	36.4
125	7.3	8.9	1.0	28.3	44.5
207	7.5	9.4	1.0	28.6	38.9
213	5.9	7.9	1.4	26.0	36.2
214	6.7	8.4	1.0	25.8	36.0
233	6.3	8.3	1.0	25.9	35.2
259	6.7	7.7	0.9	25.4	34.9

Raw Data for the Negro Women

X-ray Number	Pivotal Length	Overall Length	Calcaneal Pad	Foot Length	Calf Girth
20	6.0 cm.	7.3 cm.	1.1 cm.	--	--
22	6.6	8.5	1.1	--	--
23	6.4	8.0	1.0	24.4	33.8
24	6.6	8.0	1.0	--	--
87	6.0	7.7	1.1	--	--
91	6.3	8.0	1.2	--	--
128	6.3	7.9	1.3	--	--
129	5.8	7.2	1.3	23.9	32.2
132	6.4	8.3	1.0	--	--
136	6.4	7.7	1.6	26.2	44.2
137	6.8	8.1	1.4	25.9	37.9
150	6.2	8.0	0.9	24.9	31.1
151	5.9	7.1	0.9	24.9	32.5
152	5.8	6.8	1.4	23.2	36.8
153	6.4	8.0	0.9	25.4	33.5
160	5.8	7.2	1.1	23.3	29.5
172	5.9	7.6	0.9	25.3	34.2
180	6.2	7.8	1.2	25.4	34.8
182	6.2	7.3	1.6	24.6	33.8
183	6.3	7.8	1.4	26.3	33.7
184	5.7	7.3	1.1	24.8	30.6
187	6.2	7.9	0.9	25.3	34.3
188	6.1	7.7	1.0	25.8	33.7
191	5.7	7.4	1.0	24.5	31.4
201	6.6	8.5	0.8	26.4	38.7
202	6.0	7.8	0.8	25.8	33.6
203	6.3	7.6	1.4	25.0	39.8
204A	6.0	7.6	1.3	24.9	36.8
204B	6.1	7.6	1.2	23.7	33.0
220	6.2	8.0	1.0	25.7	32.5
229	5.7	7.1	1.1	23.0	31.8
230	6.9	8.4	1.0	25.4	33.0
231	6.0	7.5	0.9	24.1	31.4
235A	6.6	8.2	1.3	28.1	33.0
236A	6.5	8.4	0.8	25.6	35.5
237B	5.6	7.1	1.0	24.7	36.0
238B	6.0	7.3	1.5	24.5	39.7
242	5.7	7.1	1.2	23.3	31.6
243	6.5	7.8	1.1	24.8	38.1

Raw Data for the Caucasian Women

X-ray Number	Pivotal Length	Overall Length	Calcaneal Pad	Foot Length	Calf Girth
1	6.4 cm.	8.1 cm.	1.0 cm.	--	--
2	6.1	7.4	1.2	23.5	32.4
3	5.8	7.5	1.0	--	--
4	5.7	7.1	0.9	--	--
5	6.1	7.6	0.9	--	--

Raw Data for the Caucasian Women (Cont'd)

X-ray Number	Pivotal Length	Overall Length	Calcaneal Pad	Foot Length	Calf Girth
6	6.3 cm.	7.6 cm.	1.0 cm.	24.0 cm.	32.7 cm.
7	5.8	7.1	1.1	--	--
8	6.3	7.9	1.0	24.3	31.6
9	6.4	7.6	1.1	--	--
10	5.7	7.3	0.9	--	--
11	5.6	7.4	1.1	22.8	36.0
12	5.9	7.5	1.0	--	--
13	5.6	7.3	1.1	23.1	32.9
14	5.8	7.2	0.9	--	--
15	5.3	6.8	0.8	--	--
16	6.1	7.6	1.0	--	--
17	5.6	6.8	1.0	--	--
18	5.2	6.9	0.9	--	--
19	6.6	8.1	0.8	--	--
21	6.0	7.5	0.7	--	--
25	6.1	7.5	1.1	--	--
26	5.5	6.9	1.3	--	--
27	5.7	7.4	1.1	--	--
28	6.1	7.6	1.1	--	--
29	6.3	8.1	0.8	24.0	34.1
30	6.0	7.6	0.7	--	--
31	6.2	7.4	0.9	--	--
32	6.2	7.2	1.3	--	--
33	6.8	8.3	0.7	--	--
34	6.4	8.0	0.9	--	--
35	6.2	7.3	0.9	--	--
36	6.4	7.9	0.8	--	--
37	5.9	7.2	0.9	--	--
38	6.5	7.7	0.9	--	--
40	6.2	7.5	1.3	--	--
41	6.2	7.5	1.0	--	--
42	5.9	7.2	0.8	--	--
43	5.9	7.4	0.9	22.7	39.7
44	5.8	7.2	1.1	--	--
45	6.1	7.3	0.9	--	--
51	5.9	7.6	0.8	--	--
54	5.5	7.1	0.9	--	--
56	6.0	7.1	1.1	--	--
57	5.9	7.1	1.0	--	--
67	5.8	7.4	0.7	23.5	34.1
68	6.1	7.7	1.1	26.4	42.1
69	5.8	7.8	1.3	24.5	34.3
70	6.2	7.7	0.8	--	--
71	6.1	7.7	1.1	--	--
72	5.4	6.8	1.0	22.1	32.9
73	5.4	6.7	0.8	--	--
74	6.0	7.2	0.9	23.0	35.0
75	5.8	7.2	1.0	--	--
76	6.1	7.8	0.8	24.6	35.4
77	5.6	6.9	1.0	22.0	34.7
78	5.9	7.5	0.8	--	--

Raw Data for the Caucasian Women (Cont'd)

X-ray Number	Pivotal Length	Overall Length	Calcaneal Pad	Foot Length	Calf Girth
79	5.9 cm.	7.6 cm.	0.8 cm.	--	--
80	4.9	6.7	0.7	--	--
81	5.2	6.8	1.1	--	--
82	5.5	6.9	0.9	--	--
83	5.5	6.9	1.0	--	--
84	5.9	7.5	0.7	--	--
85	6.1	7.9	0.9	--	--
86	6.1	7.6	0.9	--	--
88	5.6	7.3	0.9	--	--
89	6.0	7.1	1.3	--	--
90	5.7	7.1	0.7	--	--
92	5.3	6.9	0.9	--	--
93	6.0	8.0	1.1	--	--
94	6.0	7.9	0.8	--	--
95	6.5	8.4	0.8	23.7	32.2
96	6.8	8.1	0.9	--	--
97	5.7	7.3	0.7	--	--
98	6.9	8.6	0.9	26.3	37.1
99	5.9	7.5	0.6	--	--
100	5.6	7.2	0.7	--	--
101	5.3	6.6	1.2	--	--
102	5.5	6.7	1.0	--	--
103	5.7	7.2	1.3	--	--
104	5.8	7.1	0.7	--	--
105	5.4	7.0	1.1	--	--
106	5.1	6.5	1.2	--	--
107	5.8	7.5	1.0	--	--
108	5.2	6.8	0.9	--	--
109	5.4	7.1	0.9	--	--
110	5.5	7.2	0.8	--	--
111	6.0	7.7	0.8	--	--
112	6.0	7.3	1.0	--	--
126	6.4	8.1	0.9	--	--
127	6.1	7.7	1.2	--	--
130	6.1	7.8	0.8	--	--
133	6.2	8.0	0.6	--	--
134	6.2	7.5	0.9	--	--
135	5.8	7.3	1.0	--	--
138	6.2	7.6	0.7	24.2	31.1
139	5.5	7.2	0.9	25.0	34.1
140	6.2	7.7	1.0	24.6	38.4
141	5.8	7.2	0.9	27.7	34.4
142	5.9	7.6	1.0	24.3	34.6
143	5.9	6.9	0.8	22.2	33.5
144	5.6	7.1	1.0	27.7	34.9
145	6.7	8.0	1.0	25.2	40.2
146	5.8	7.6	0.8	24.2	31.0
147	5.7	7.2	1.1	24.0	36.2
148	6.1	7.4	0.9	23.7	34.0
149	6.7	8.0	0.9	24.2	40.2
154	5.6	7.3	0.9	23.7	31.9

Raw Data for the Caucasian Women (Cont'd)

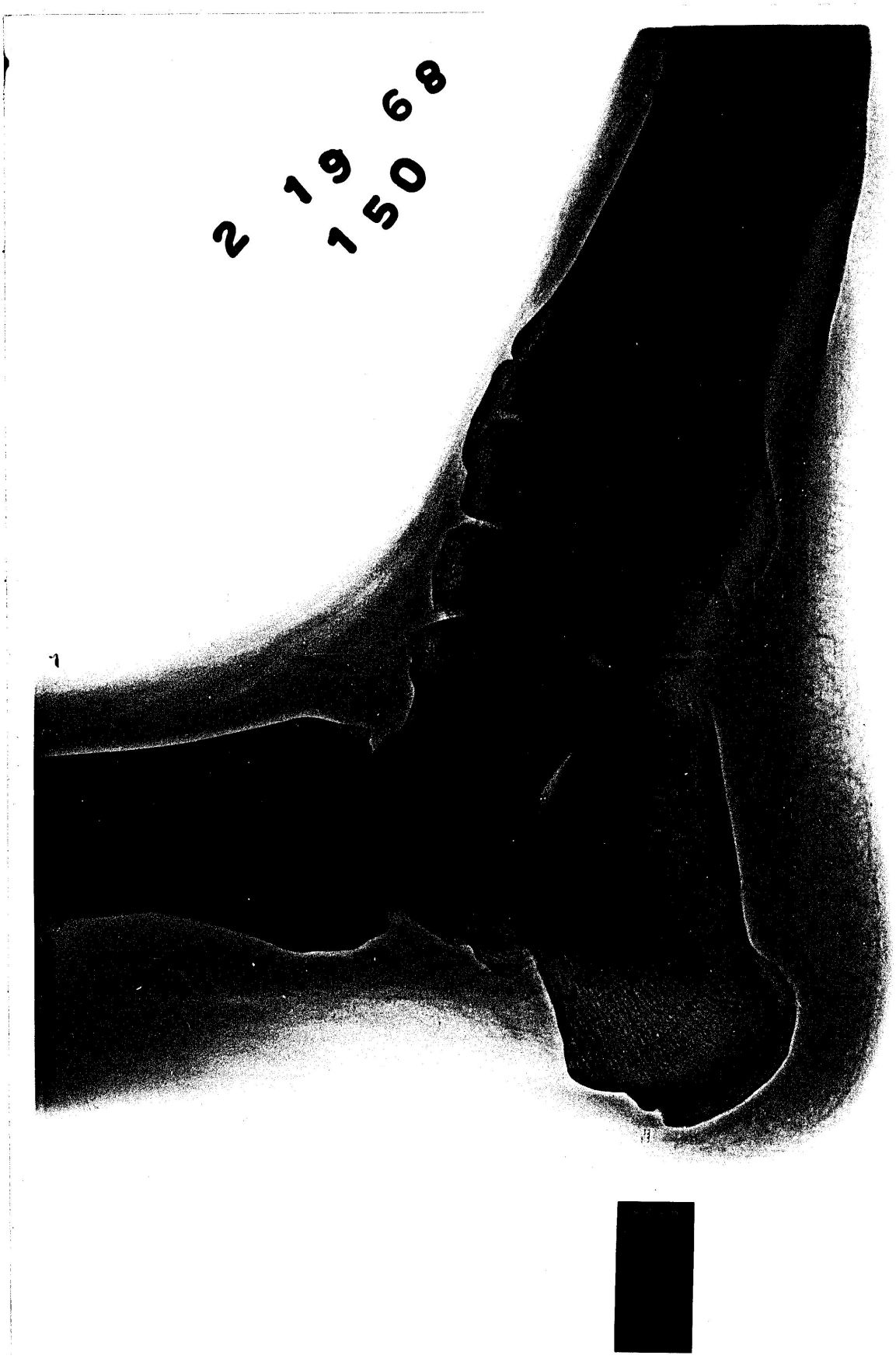
X-ray Number	Pivotal Length	Overall Length	Calcaneal Pad	Foot Length	Calf Girth
155	5.3 cm.	6.9 cm.	0.8 cm.	22.6 cm.	30.6 cm.
156	5.9	7.4	1.0	24.3	34.3
157	5.9	7.3	1.0	23.4	34.3
158	6.2	7.5	0.9	24.5	38.4
159	5.6	7.3	0.7	23.9	30.1
161	6.4	8.1	1.0	27.0	38.3
162	6.0	7.7	1.2	25.5	37.8
163	5.7	7.1	1.1	23.6	38.6
164	6.3	8.1	0.9	24.9	36.5
165	5.9	7.4	0.7	23.7	35.7
166	4.7	6.6	0.7	21.5	27.6
167	6.1	7.9	1.1	23.5	33.7
168	5.5	7.3	0.7	22.1	33.0
169	5.5	6.8	1.1	22.4	34.3
170	5.9	7.7	0.7	25.0	31.8
171	5.8	7.2	0.8	23.0	34.0
173	6.3	7.9	0.9	25.2	37.5
174	5.8	7.4	0.9	24.9	31.9
175	5.7	7.3	0.7	23.2	33.0
176	6.3	7.7	0.9	24.5	36.0
177	5.9	7.5	0.8	24.2	27.9
178	5.8	6.9	0.9	22.6	31.8
179	5.6	6.9	1.3	24.2	33.7
181	5.9	7.3	1.0	22.8	40.0
185	5.1	6.7	1.0	22.3	34.0
186	5.7	7.3	1.1	23.6	34.3
189	6.5	7.9	0.7	24.8	33.7
190	6.7	8.4	1.0	26.3	38.3
192	6.2	7.5	1.1	23.7	36.2
193	5.9	8.0	0.9	24.4	34.3
194	5.9	7.7	1.3	24.4	33.0
195	5.8	7.5	0.8	23.8	35.4
196	6.2	7.6	0.9	24.6	31.7
197	6.4	7.6	0.7	24.7	34.4
198	5.7	7.4	1.0	25.0	35.0
199	5.7	7.5	0.8	24.1	35.5
200	5.5	7.1	0.9	23.3	34.2
210	5.8	7.6	0.6	23.8	34.7
211	6.1	7.8	1.0	24.6	33.1
212	6.0	7.8	0.9	24.8	32.7
215	5.4	7.1	0.9	23.2	31.6
216	6.4	7.2	0.8	23.8	32.0
217	6.0	7.7	0.9	26.5	32.4
218	5.5	7.0	0.9	24.0	37.2
219	5.6	7.1	0.7	23.0	33.2
221	5.8	7.5	0.7	22.3	29.3
222	6.2	8.1	0.9	24.9	37.0
223	5.8	7.6	1.0	23.2	32.5
224	5.8	7.5	0.8	23.0	34.9
225	5.7	7.0	1.2	23.5	33.2
226	6.0	7.6	0.8	24.0	34.4

Raw Data for the Caucasian Women (Cont'd)

X-ray Number	Pivotal Length	Overall Length	Calcaneal Pad	Foot Length	Calf Girth
227	6.1 cm.	7.5 cm.	0.8 cm.	24.3 cm.	33.9 cm.
228	6.0	7.4	0.9	23.3	42.8
232	5.9	7.2	0.8	22.6	34.3
234	6.1	7.6	1.2	24.4	36.3
235B	6.1	7.3	0.8	24.4	38.9
236B	5.8	7.2	0.7	23.5	32.6
237A	6.4	8.0	0.6	24.4	35.1
238A	6.6	7.0	0.8	22.6	33.7
239	5.6	7.0	0.9	22.1	31.3
240	5.7	7.1	1.4	23.7	32.7
241	5.3	6.9	0.9	22.5	32.2
244	5.4	6.8	0.8	21.5	31.0
245	5.5	6.7	0.9	21.4	34.5
246	6.0	7.6	1.0	25.6	34.8
247	5.1	6.6	0.6	20.2	31.4
248	5.9	7.3	0.9	23.6	36.0
249	5.5	7.2	1.1	22.8	33.2
250	5.9	7.9	0.9	24.2	35.0
251	5.4	7.1	1.2	24.0	38.0
252	5.6	7.2	1.0	23.6	33.8
253	5.3	7.0	0.7	21.8	32.7
254	5.2	6.8	0.8	20.8	28.8
255	5.6	7.3	0.8	24.0	30.9
256	6.0	7.9	0.9	24.1	37.4
257	6.3	7.9	1.1	25.1	32.9
258	6.4	8.0	1.1	25.0	37.2
260	5.5	7.2	0.8	23.5	30.9
261	5.9	7.5	0.9	24.1	32.8

APPENDIX B

PHOTOGRAPH OF A REPRESENTATIVE X-RAY NEGATIVE


2 19 68
150

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