A SURVEY OF SELECTED ANTHROPOMETRIC MEASUREMENTS OF UNDERGRADUATE COLLEGE WOMEN WITH SPECIAL REFERENCE TO THE TEACHING OF SPECIFIC PHYSICAL EDUCATION SKILLS AND THE DESIGN AND CONSTRUCTION OF ATHLETIC EQUIPMENT

A DISSERTATION
SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY IN PHYSICAL EDUCATION
IN THE GRADUATE SCHOOL OF THE
TEXAS WOMAN'S UNIVERSITY

COLLEGE OF
HEALTH, PHYSICAL EDUCATION, AND RECREATION

BY
MARILYN JOYCE PRUITT, B. S., M. ED.

DENTON, TEXAS
AUGUST, 1968

Texas Woman's University

Denton, Texas

August 19 68

We hereby recommend that the dissertation prepared under our supervision by Marilyn Joyce Pruitt entitled "A SURVEY OF SELECTED ANTHROPOMETRIC MEASUREMENTS OF UNDERGRADUATE COLLEGE WOMEN WITH SPECIAL REFERENCE TO THE TEACHING OF SPECIFIC PHYSICAL EDUCATION SKILLS AND THE DESIGN AND CONSTRUCTION OF ATHLETIC EQUIPMENT"

be accepted as fulfilling this part of the requirements for the Degree of DOCTOR OF PHILOSOPHY

Committee:

Chairman

Accepted:

Dean of Graduate Studies

To my Christian parents who have been an inspiration to me and have motivated me to greater aspirations I affectionately dedicate this dissertation.

ACKNOWLEDGMENTS

The writer wishes to express her genuine gratitude and appreciation to Doctor Richard V. Ganslen for his interest, assistance, and unselfish guidance of this dissertation. To the rest of the dissertation committee, Doctor Claudine Sherrill, Mr. Bertron Lyle Jr., Doctor Joel Rosentswieg, and Mr. George Vose, the writer expresses a grateful thank you for their cooperation.

Heart felt appreciation is extended to the students who served as subjects in this survey.

The writer is indebted to her "Cleburne Parents", the A. L. Moores and her patient roommate, Mert Paben, for their inspiration and support during the writing of this dissertation and the attainment of the Doctor of Philosophy degree.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ILLUSTRATIONS

CHAPTER I

ORIENTATION TO THE STUDY

Introduction

The human physique is increasing steadily in weight and height from generation to generation. From a practical as well as a scientific standpoint, it is desirable to determine the extent of these changes of dimensions in the mature female figure. What are the practical implications from this growth trend? Marylou Adam illustrates the problem with the following statement:

> consider, for example, the effect this [growth trend] might have on business. Manufacturers of household equipment, automobiles, furniture and clothing, to name a few, will need to be familiar with this trend, and adjust their businesses accordingly.[1]

Personnel of the armed forces require improved uniforms; the general public may need to be provided with gas masks; airplane cockpits must be fitted to men, and eventually to women; and prostheses must be made to fit comfortably and to manipulate easily. If diseases have predisposition for certain body builds or specific genetic prototypes

---

[1]Marylou Merkel Adam, "Secular Trends in Women's Body Proportions" (unpublished Master's thesis, Pennsylvania State University, 1959), p. 2.

educators should become cognizant of these facts now.[1]

Anthropometry makes documentation of body size changes possible. The rapidly changing population, in the United States makes it <u>mandatory</u> to research the various proportions of the human anatomy, categorizing body build and identifying tendencies of increased growth. Earl W. Count recognizes this need for anthropometric studies when he noted this observation:

> is that man's practical problems with himself cannot wait until he has resolved theoretically. We must measure man now and here.[2]

Studies based upon anthropomethic measurements should be complementary to human efficiency and provide for greater safety, comfort and convenience. Anthropometry should contribute to the designing of furniture, automobiles, clothing and athletic equipment. Adam[3] points out that manufacturers of automobiles are continually advertising "more leg room" in their cars; and Tall Girl Shops, which were unthinkable in the 1920's, now number more than 2,000. Adam[4] further suggests that manufacturers should be interested in obtaining data revealing how much the average body size has changed and what apparently the average size of the contemporary female figure is.

---

[1]Earl W. Count, "Statement of General Objectives," <u>Annals of the New York Academy of Sciences</u>, Vol. LXIII, Art. 4 (November 28, 1955), p. 435.

[2]<u>Ibid</u>. [3]Adam, <u>Op</u>. <u>Cit</u>., p. 3. [4]<u>Ibid</u>.

A better understanding of dynamic actions of the human mechanism can prove valuable in the teaching and coaching of physical education skills. Dempster emphasizes this relationship between dynamic anthropometry and muscular function when he stated:

> If a dynamic anthropometry relating to movement patterns is to be developed, it must proceed on an understanding of the nature of body kinematics and the importance of forces in relation to posture and movement.[1]

The capacity for quintessence of movement is dependent to a large extent upon an understanding of the kinematics of the human body. This knowledge not only denotes the copious possibilities of locomotor patterns, but also points out the reasons for and the laws of physics which regulate movement. Man displays his most conspicuous human characteristics in his movement patterns. The ease with which he moves in space and performs intricate motor acts signifies the symmetry that exists between the construction of the physical body and its motor tasks. It is only after attaining some measure of understanding of the body in motion that one begins to appreciate the extent to which the bodily proportions measured at rest exercise their influence on a motor skill, such as a complex golf swing or a powerful tennis stroke.

---

[1] Wilfrid Taylor Dempster, "The Anthropometry of Body Action," Annals of the New York Academy of Sciences, Vol. LXIII, Art. 4 (November 28, 1955), p. 583.

Recognition of the fact that intelligent control of even the most common patterns of movement depends upon the muscles and bone proportions lends stature to their study. Calipers and tape measures cannot compete on even terms with the experienced eye or a motion picture camera in evaluating movement patterns of an aesthetic conformation. Scientific measurements demonstrate their advantages when more subtle relationships between movement and bodily proportions are sought, such as those encountered in the dynamics of motion.

Statement of the Problem

This study comprised an intensive anthropometric measurement program encompassing 1,049 women enrolled in the Texas Woman's University during the academic year of 1967-1968. A systematic investigation was conducted that concentrated upon the critical examination of selected anthropometric measurements which have scientific, as well as practical, implications for the teaching of the golf swing and tennis stroke and the selection and design of athletic equipment for women.

Rationale of the Study

Apparently, there have been few systematic attempts to relate the anthropometric measurements of women to the design and construction of athletic equipment. This however, has not always been true with respect to other biologically related sciences. Krogman, the distinguished anthropometrist, expressed the fact that anthropometric measurements can contribute to science when he wrote

> it is inescapable . . . that constitutional anatomy has something to offer human biology. It is an important approach to the study and understanding of the human body.[1]

Parnell indicates the need for systematic anthropometric measurements when he states that

> there is much that can be measured, and physique is one obviously accessible aspect. Anthropometry has, until recent years, tended to stick in a rut of traditional skeletal measurements, or else composite measurements embracing tissues of varying function. Thus it has tended systematically to rob itself of the greater functional discrimination and understanding which may be derived from studying soft tissues such as fat and muscle.[2]

Numerous studies indicate that physique or body build is fundamental as a foundation of reference in attempts to shed light upon health, types and degrees of physical fitness, athletic performance, and the personality traits

---

[1]Wilton Marion Krogman, "The Historical Aspect of the Study of Human Constitutional Types," Cibia Symposia, George Rosen (ed.) Summit, New Jersey: Cibia Pharameceutical Products Inc., (1941), p. 1086.

[2]R. W. Parnell, Behavior and Physique (London: Edward Arnold Ltd., 1958), p. 1.

of human beings.[1,2,3,4,5,6]

Physical education instructors are faced continuosly with the inevitable problem of adapting the student to the equipment provided rather than having equipment which is available and appropriate to the student's physical traits in teaching everyday physical education skills. For example, teachers of golf are confronted constantly with the dilemma of teaching the mechanics of a precise skill, such as the golf swing, with clubs whose lengths are out of proportion of the need of the "average" class of college women. Even little league baseball players have a choice of bats when they step up to the plate!

---

[1]George Draper, C. W. Dupertuis, and J. L. Caugley, Jr., Human Constitution in Clinical Medicine (New York: Paul B. Hoeber Inc., 1944).

[2]F. I. Wertheimer and Florence E. Hesketh, "The Significance of the Physical Constitution in Mental Disease," Medicine, Vol. V (1926), p. 375.

[3]T. K. Cureton, et at., Physical Fitness Appraisal and Guidance, "Appraisal of Body Type as an Approach to Health and Fitness Guidance," (St. Louis: C. V. Mosby Co., 1947), pp. 70-134.

[4]Soini Pere, et al., "Correlation Between Performance and Physique in Finnish Athletes," American Journal of Physical Anthropology, Vol. XII (1954), pp. 201-208.

[5]Karl Bookwalter, "The Relationship of Body Size and Shape to Physical Performance," Research Quarterly, Vol. XXIII (October, 1952), pp. 271-279.

[6]E. Kretschmer, Physique and Character, (W. J. Sprott, ed.), (New York: Harcourt, Brace, 1926).

It may be possible to minimize the foregoing difficulty by a systematic anthropometric program which will identify anatomical measurements which are related specifically to items of equipment and the execution of skills *per se*, and which will translate this intelligence into the design of suitable items of equipment.

Definitions and Explanations of Terms

For the purpose of clarification, the following definitions and/or explanations of terms are accepted for use as they relate to this study.

1. *Anthropometry*: Hrdlička defines anthropometry as

   > . . . a system of techniques. It is the systematized art of measuring and taking observations on man, his skeleton, his brain, or other organs, by the most reliable means and methods, for scientific purposes.[1]

2. *Anthropometric Measurements*: McCloy states that anthropometric measurements are

   > . . . the objective measurements of certain structures and the functions of the body. Measurement of the body includes the measurement of total height, width of shoulders, chest, hips, and knee, depth of chest, and such measures of bulk as weight.[2]

---

[1] Aleš Hrdlička, *Practical Anthropometry* (Philadelphia: Wistar Institute of Anatomy and Biology, 1939), p. 3.

[2] C. H. McCloy, *Apprasing Physical Status the Selection of Measurements*, Studies in Child Welfare, Vol. XII, No. 2 (Iowa City: University of Iowa, 1936), p. 10.

3. Body Build: Cureton defines body build as

> . . . the morphological or structural characteristics (total biological make-up) of the human body as reflecting qualities related to:
> 1. Health, disease, immunity.
> 2. Capacity for physical exertion and endurance.
> 3. Social adaptability through mental and personality attitudes.[1]

4. Constitution: Draper describes constitution as

> that aggregate of inherited characters modified more or less by environment which together determine the individual's reaction, successful or unsuccessful, to the stress of environment.[2]

5. Physique: Cureton's explanation of physique is both succinct and graphic when he states that "physique represents the obvious first impression due to appearance."[3]

Purposes of the Study

The general purposes of this study are:

1. To provide valuable anthropometric information which may have implications for the teaching of golf and tennis skills to undergraduate college women.

---

[1] T. K. Cureton, "Body Build as a Framework of Reference for Interpreting Physical Fitness and Athletic Performance," Research Quarterly, Vol. XII (May, 1941), p. 302.

[2] Draper, Op. Cit., p. 1.

[3] Cureton, Op. Cit., 1947, p. 19.

2. To provide authoritative anthropometric measurements of undergraduate college women for utilization by manufacturers of selected items of golf and tennis equipment for women.

Limitations of the Study

The present study was subject to the following limitations:

1. Volunteer students numbering 1,049 enrolled in the Texas Woman's University in Denton, Texas during the academic year of 1967-1968.

2. The thirty-three selected anthropometric measurements described in the appendix of this study.

3. The determination of the anthropometric measurements obtained through the use of the instruments described in the appendix of this study.

4. Applications of the date yielded to the sports of golf and tennis.

Survey of Previous Studies

The present study is different in several respects. One unique difference between it and related studies is the utilization of selected anthropometric measurements for the design and construction of selected items of athletic equipment for women. Another difference obtains in that the investigator utilized measurements not ordinarily taken in anthropometric surveys for women such as, functional and maximal arm reach, knee girth, eye height, sitting, hip breadth, sitting, arm span, waist height, sitting, buttock-leg length, and knee height, sitting.

At the present time, numerous anthropometric surveys of the male physique have been conducted by Daniels,[1] Hertzberg,[2] King,[3] and McFarland.[4] The results of these studies have provided the contemporary standards for the design and construction of automobile seats and airplane cockpits. The resultant information has been used extensively in industrial design. In the 1930's, Meredith[5] conducted research with respect to body "assessments", but concentrated his efforts primarily upon ascertaining those of children and adolescent boys.

---

[1]G. G. Daniels, et al., Anthropometry of Male Basic Trainees WADC Technical Report, 53-49 (Ohio: Wright-Patterson Air Force Base, 1953).

[2]H. T. Hertzberg, The Anthropometry of Flying Personnel WDAC Technical Report, 52-321 (Ohio: Wright Air Development Center, Wright-Patterson Air Force Base, 1950).

[3]B. G. King, "Measurement of Man For Making Machinery," American Journal of Physical Anthropology, Vol. VI (1948), p. 341-351.

[4]McFarland, et al., Human Body Size and Capabilities in the Design and Construction of Vehicular Equipment (Boston: Harvard School of Public Health, 1953).

[5]Howard V. Meredith, "The Reliability of Anthropometric Measurements Taken on Eight-and-Nine-Year Old White Males," Child Development, Vol. VII (December, 1936), p. 262-272.

In recent years, a number of studies have been conducted to determine "body measurement changes" of our population. Several studies were conducted specifically for the benefit of those involved in the garment industry in this country.[1] More recently, investigators have concentrated upon such factors as fluxuations with respect to height and weight, the relationship between physique and performance capacity, athletic achievement, physical fitness, vital capacity and motor ability, the determination of body build, estimation of body fat and geographical variation in body sizes.

The following reviews are presented as illustrative of studies which have provided guidelines and background information in the development of the present investigation.

In 1941, O'Brien and Shelton[2] conducted a study for the purpose of determining measurements which might be used for the improvement of "fit" in women's clothing and for the development of improved patterns. The 14,698 subjects utilized in this study were white residents from Arkansas, California, Pennsylvania, and the District of Columbia. Native and foreign born women eighteen years of age and older were surveyed. The investigation entailed the determination of fifty-eight measurements,

---

[1]R. O'Brien and W. C. Shelton, <u>Women's Measurements for Garment and Pattern Construction</u>, Miscellaneous Publication no. 454, (Washington, D. C.: United States Department of Agriculture in Cooperation with the W. P. A., 1941).

[2]<u>Ibid</u>.

including body weight. Three kinds of averages - the mean, median, and mode - were calculated from the data attained. The mean stature for all subjects was five feet and three inches and the mean weight, 133 and 1/2 pounds. According to O'Brien these figures differ only slightly from those given by insurance companies. From the data collected the investigators constructed a standard set of forms or mannequins of women in the United States.

Mohr and Gundlach,[1] in 1927, related physical types of 254 inmates of Joliet Prison in Illinois to reaction time and other selected psychological measures. These investigators concluded that

> . . . physique does determine certain kinds of performance, as is instanced by the types of men who excel in certain athletic events.[2]

Bookwalter,[3] in 1952 undertook a study to show the relationship of physique and level of physical development, as determined by the Wetzel Grid, with the development of elementary school boys in terms of their scores on the Indiana State Physical Fitness Test. The study included 1,977 Indiana school boys. Subjects of

---

[1] G. J. Mohr and R. H. Gundlach, "The Relation Between Physique and Performance," Journal of Experimental Psychology, Vol. X (1927), p. 123.

[2] Ibid.

[3] Bookwalter, Op. Cit.

medium or thin body build and those who were above average in size performed equally well physically. He concluded that both size and shape of the physique were related to physical performance.

In 1954, Pere, Kennas and Lelkkä[1] studied the relationship between the physique and performance of 172 top-ranking track and field male athletes. These investigators concluded that physique has little influence upon performance, and that high achievement in a given event may be reached by athletes of very dissimilar physiques!

In 1929, Jackson[2] investigated the relationship of body mass and selected physiological characteristics with emphasis upon that of vital capacity. The age range of the 1,022 female college subjects studied was from fifteen to forty-seven years with a mode of nineteen years. The majority of the subjects were of Scandanavian and German extraction, residing in Minnesota or in the neighboring states of Wisconsin, Iowa, North Dakota, and South

---

[1]Pere, Op. Cit.

[2]C. M. Jackson, "Physical Measurements of the Female Students at the University of Minnesota With Special Reference to Body Build and Vital Capacity," American Journal of Physical Anthropology, Vol. XII (1929), p. 363.

Dakota. From the seven anthropometric measurements which were assessed, the investigator concluded that the vital capacity of this group was above the average for American college women. The correlation between stature and age was insignificant for women in this study. The correlation between weight and chest girth was found to be .735. Vital capacity tended to decrease with age, and there was a slight but insignificant correlation between body build and vital capacity.

From the voluminous literature pertaining to body build examined by the present investigator, it is apparent that general body build has been accepted as an assessment with a wide range of values from an extreme linear to an extreme lateral type, characterized by a continuous unimodal distribution. Such investigators as McCloy,[1] Molitch,[2] Dublin,[3] Draper,[4] and Sargent[5] have

---

[1]McCloy, Op. Cit., 1936.

[2]M. Molitch, "Body Build Factor in Basal Metabolism of Boys," American Journal of Diseases of Children, Vol. L (1935), p. 621.

[3]Louis Dublin and Herbert Marks, "The Build of Women and Its Relation to Their Mortality," The Association of Life Insurance Medical Directors of America (1938).

[4]George Draper, Disease and the Man (London: Kegan Paul, 1930).

[5]Dudley A. Sargent, "Physical Proportions of Typical Man," Scriber's Magazine, (July, 1887), pp. 3-17.

held this viewpoint. In 1940, Jorgenson and Hatlestad[1] combined the data from two dissertations to evaluate a number of anthropometric indices most frequently used in determining body build. Their objective was to determine which physical measure best specifies the body build of a given individual. They first constructed T-scales utilizing the best of these anthropometric indices (frequently used to identify body build) to determine whether there were separate and distinct categories of body build in 300 male and 200 female college students. The female subjects were enrolled in the Kansas State Teachers College, and the male subjects were from the State University of Iowa. Twenty-eight measurements were assessed. From the data presented in this investigation, the researchers concluded that body build can best be understood in terms of a continuous distribution from one extreme to the other, with no distinct categorical types as suggested by various other authors.

It is generally conceded that overweight is a dangerous condition and that increasing overweight directly increases the "bleakness of the prospectus."[2]

---

[1]N. W. Jorgenson and S. Lucille Hatlestad, "Determination and Measurement of Body Build in Men and Women College Students," Research Quarterly, Vol. XI (December, 1940), pp. 60-77.

[2]"Body Conformation, Coronary Heart Disease, and Longevity," Nutritional Review, Vol. XXV (January, 1967), p. 5.

There are serious problems in the categorization and meaning of overweight or underweight as defined by height-weight data alone![1]

Sloan,[2] undertook a study in 1962 to determine the relative validities of various skinfold and girth measurements as indices of the proportion by weight of fat in the bodies of fifty healthy university women from ages seventeen to twenty-five. It was of interest to note the low correlation between weight-height and density, thus illustrating the inadequacy of the assessment of body fat on the basis of weight and height alone! The skinfold fat measurements which yielded the highest correlation ($r = + .92$), with a composite criterion of skinfold, was that measure taken over the crest of the ilium. The best predictor of body density from skinfold measurements was the iliac crest fat measurement and fat fold over the tricep muscle on the posterior aspect of the arm.

An article appearing in the Journal of American Medical Association,[3] 1937, emphasized the fact that

---

[1] Ibid.

[2] A. W. Sloan, et al., "Estimation of Body Fat, in Young Women," Journal of Applied Physiology, Vol. XVII (November, 1962), pp. 967-970.

[3] L. B. Chenoweth, "Increase in Height and Weight and Decrease in Age of College Freshmen Over a Period of 20 years", Journal of American Medical Association, Vol. CVIII (1937), pp. 354-356.

students were entering college at an earlier age than those who enrolled twenty years previous to that date. Records of the height and weight of 8,964 young men and 4,124 women entering the University of Cincinnati in Cincinnati, Ohio, from 1916 to 1935 were reviewed by Chenoweth.[1] The results indicated that freshman students were admitted at an earlier age and were heavier and taller than their predecessors. The author observed that there is no definite explanation with respect to the cause of this increase in size except the recognition of the possibility of the influence of better nutrition in childhood, higher standards of living, a decrease in communicable diseases, and a higher degree of health intelligence among the general population than obtained formerly.

Good health is of the utmost importance to every individual. Valid indices of its presence or absence have been sought through a study of almost all physiological functions. A simple health indicator, body weight, with emphasis upon weight fluxuations, is frequently evaluated. The use of any health indices, however, implies the presence of adequate standards and norms. A study which attempted to establish normative scale for specific age levels and geographical locations was conducted by Turner,[2] in 1943.

---

[1] Ibid.

[2] Abbey Turner, "Body Weights Optimal for Young Adult Women," Research Quarterly, Vol. XIV (October, 1943), pp. 255-276.

This study reported on the Mount Holyoke Studies made by the Willoughby System, (to calculate optimal weights). The following is an explanation of the Willoughby System.

> The measurements employed by the Willoughby as criteria of skeletal size are widths at three levels: biacromial, bi-iliac, and bi-trocanter; three girth; wrist, knee,ankle each taken on both left and right sides; and total weight. This equivalent ankle girth, representing the general width and thickness of the whole skeleton, is then converted by a table made from a study of many relationships into a weight factor which gives in pounds the weight of one inch of a cylindrical figure equivalent in cross section area to that of the optimal body and of a height equal to the height of the body. To secure the optimal weight this weight factor is multiplied by the actual height in inches.[1]

A regression equation was given as an alternative method of weight prediction. Turner used the technique of regression coefficient for prediction of optimal body weight for college women and compared this coefficient with other systems such as Dearborn and Rothney, Medico-Actuarial, Pryor System and Bollin System. Turner utilized a group of 241 entering college students ranging in age from eighteen to nineteen years.

Donelson,[2] and his associates in 1940 studied:

---

[1] Ibid., p. 256.

[2] E. G. Donelson, et al., "Anthropometric Data on College Women of the Middle States," American Journal of Physical Anthropology, Vol. XXVII (1940), pp. 319-332.

(1) the late phase of growth in young men, (2) new points to be fixed in the trend with respect to the size of college women, and (3) formulation of norms for the ages and localities represented in the investigation. The states represented in the study were Iowa, Kansas, Minnesota, Ohio, and Oklahoma which are in the same general geographical location in the United States. These investigators utilized 1,013 college women ranging in age from sixteen to thirty years. It was noted however, that differences in the eight anthropometric measurements taken were found among the subjects representive of the various states in which they resided.

In 1966, Powell[1] undertook a study of the height and weight of 1,350 freshman college women. Skinfold assessments from 221 freshmen and sophomore women were used to establish standards for this particular parameter. Skinfold values noted were higher than those previously reported in nationally accepted norms.

Comprehensive anthropometric surveys of women are not readily available. They are needed urgently in the human physique.[2] Data from many different localities

---

[1]A. T. Powell, "Percentiles for Evaluation of Body Measurements by College Students," Journal of Home Economics, Vol. LVIII (December, 1966), pp. 792-794.

[2] Jackson, Op. Cit.

are desirable also in order to facilitate a study of regional and racial diversities with respect to such measurements.

After a comprehensive review of the literature, the investigator concluded that this investigation does not duplicate any study previously reported. The investigator's present study is similar to the foregoing studies reviewed in that she employed the use of selected anthropometric and skinfold measurements, and volunteer undergraduate students served as subjects.

Summary

Through the application of the laws of physics and present-day anthropometric data "optimal system performance through effective utilization of human capacities"[1] can be achieved. The study of the structure of muscles and the proportion of bones provides valuable data which have implications for the teaching and coaching of physical education skills, as well as many other practical connotations. Elftman expresses succinctly

---

[1]Harold P. Van Cott and James W. Altman, Procedures For Including Human Engineering Factors in the Development of Weapon Systems WADC Technical Report, 56-488, AD-97305, (Wright Air Development Center Air Research and Development Command United States Air Force, Ohio: Wright-Patterson Air Force Base, 1956).

the need for anthropometric research when he states

> the 40 per cent of the human body devoted to muscle has long been favorably received by cannibals; it is time that the civilized world added its appreciation[1]

Numerous research studies related to the topic being investigated were examined; and the writer presented a summary of thirteen studies considered applicable to the development of this research project. Also, included in the first chapter were the Statement of the Problem, the Rationale of the Study, Definitions and Explanations of Terms, Purposes of the Study, and the Limitations of the Study.

Chapter II includes a detailed description of the procedures employed in the development of this study.

---

[1]Herbert Elftman, "Body Dynamics and Dynamic Anthropometry," Annals of the New York Academy of Sciences, Vol. LXIII Art. 4, (November 28, 1955), p. 556.

CHAPTER II

METHODS AND PROCEDURES FOR THE DEVELOPMENT OF THE STUDY

The development of this study will be discussed in this chapter under the following major headings: Sources of Data, Preliminary Procedures, Procedures for Obtaining Subjects, Description and Techniques of Assessing the Measurements, Treatment of the Data, Preparation of the Final Written Report, and Summary.

Sources of Data

The data utilized in this inquiry were gathered from both documentary and human sources. The documentary sources included books, periodicals, theses, dissertations, pamphlets, and other published and unpublished reports of research related to all aspects of the study. The human sources included 1,049 volunteer women enrolled in the Texas Woman's University, Denton, Texas, during the academic year of 1967-1968. Sources of authoritative advice through personal correspondence were Doctor Wesley Dupertuis,[1] Professor of Clinical Anthropology,

---

[1]Letter from C. Wesley Dupertuis, Professor of Clinical Anthropology, Eugene McDermott Laboratory of Clinical Anthropology, Cleveland, Ohio, December 4, 1967.

Doctor Josef Brozek,[1] Professor of Psychology, and H. T. E. Hertzberg,[2] Research Physical Anthropologist. A personal interview was held with Byron Nelson,[3] the distinguished professional golfer. Byron Nelson is the only man in golf history who has had a professional golf tournament named in his honor: The Byron Nelson Classic.

Preliminary Procedures

In the development of the present study, the investigator outlined and adhered to the following procedures. The investigator reviewed the available literature related to the various aspects of this investigation. Permission was secured from Doctor Anne Schley Duggan, Dean of the College of Health, Physical Education and Recreation, at the Texas Woman's University, Denton, Texas, to conduct the study utilizing students, members of the staff, equipment and facilities of the College of Health, Physical Education and Recreation during the academic year of 1967-1968. The investigator delineated the

---

[1]Letter from Josef Brozek, Department of Psychology Lehigh University, Bethlehem, Pennsylvania, November 8, 1946.

[2]Letter from H. T. E. Hertzberg, Research Physical Anthropologist, Department of the Air Force, 6570th Aerospace Medical Research Laboratories (AFSC) Wright-Patterson Air Force Base, Ohio 45433, June 24, 1968.

[3]Personal Interview with Byron Nelson, Professional Golfer, Roanoke, Texas, June 8, 1968.

selected anthropometric measurements to be taken, and the appropriate insturments were purchased from the Narragansett Gymnasium Equipment Company,[1] with the exception of the USAMRNL Skinfold Calipers[2] and an item of equipment which was developed in the investigator's laboratory which appears on page 111 of the appendix. A suitable form for recording the thirty-three measurements to be assessed was constructed and submitted to the committee members and was revised in accordance with suggestions. An additional measurement, the waist height, sitting, was added to the recording form on the advise of the committee. This recording form appears on page 101 of the appendix.

The investigator prepared and presented a tentative outline of the study on March 14, 1968, in a Graduate Seminar at the Texas Woman's University. On the basis of the suggestions and recommendations which accrued from the seminar, the tentative outline was revised and approved by the members of the dissertation committee. A copy of the approved prospectus of the dissertation was filed in the office of the Dean of Graduate Studies at the Texas Woman's University.

---

[1]Narragansett Gymnasium Equipment Catalogue, (Moberly, Missouri: Narragansett Gymnasium Equipment Company, 1965), 110 West Carpenter Street, Moberly, Missouri.

[2]Manufactured by V. R. Gersmehl, 3817 Warren Avenue, Cheyenne, Wyoming, United States of America.

Procedures for Obtaining Subjects

The investigator secured permission from the Dean of the College of Health, Physical Education and Recreation at the Texas Woman's University, to utilize volunteer students enrolled in the required program of Health and Physical Education. These girls were measured in the anthropometric laboratory from eight o'clock A.M. until noon, and from one-thirty o'clock until five o'clock P.M. The time required to measure each subject was approximately twelve minutes. The period in which all of the date were collected extended from February 14, 1968, through May 21, 1968.

Description and Techniques of Assessing the Anthropometric Measurements

The measurements taken in this study were the results of personal correspondence and telephone conversations with Doctor C. Wesley Dupertuis[1] and additional measurements were collected particularly pertinent to the golf swing and the tennis stroke. Subsequent discussion with Byron Nelson[2] affirmed the usefulness of these measurements.

---

[1]Dupertuis, _Op_. _Cit_.

[2]Nelson, _Op_. _Cit_.

The thirty-three anthropometric measurements used in this study by description were taken in the following order:

1. arm span
2. weight
3. stature
4. sitting height
5. shoulder height, sitting
6. hip breadth, sitting
7. eye height, sitting
8. knee height, sitting
9. buttock-knee length
10. buttock-leg length
11. maximal reach
12. functional reach
13. hand span
14. hand length
15. biceps
16. knee circumference
17. calf circumference

The subjects were then taken into a private room and the following measurements were assessed while the subjects were wearing their undergarments:

18. biacromial breadth
19. bideltoid breadth
20. hip breadth

21. chest breadth
22. knee breadth
23. bust circumference
24. chest circumference
25. waist circumference
26. hip circumference
27. upper-thigh circumference
28. chest depth
29. crotch height
30. waist height, sitting
31. triceps skinfold
32. scapula skinfold
33. umbilicus skinfold

These foregoing measurements are described in detail in the appendix on pages 103 through 109.

It seems appropriate at this time to describe the procedure followed while taking the three skinfold fat assessments. A substantial proportion of the body fat lies in the subcutaneous tissue. In many parts of the body this subcutaneous tissue is affixed loosely to the underlying tissue and may be "pinched" between the thumb and forefinger into a fold. By applying some form of caliper to this fold of skin and subcutaneous tissue the fold can be measured quite accurately. This method of measurement has been used extensively in order to give an estimate of body fat by those concerned with child growth and development, body density, fat distribution, nutrition and in anthropometric surveys.

Procedures for measurement and skinfold calipers have undergone substantial improvement in recent years. Today calipers which maintain constant tension are available and thus make possible more accurate and reliable measurements than in previous years. The caliper used in this study was kept at the standard value of ten grams per square millimeter of jaw surfaces on the skinfold.

The skinfold included two thicknesses of skin and subcutaneous fat, but neither muscle or fascia.[1,2,3] The skinfold was lifted with the thumb and index finger and held while the caliper was applied approximately one centimeter away from the thumb. A firm hold on the skinfold was preferred; the jaws of the caliper were applied so that the critical pressure on the skinfold was exercised by the constant surfaces of the instrument. Only the skinfold measurements were taken three times and

---

[1] D. A. W. Edwards, et al., "Design and Accuracy of Calipers for Measuring Subcutaneous Tissue Thickness," British Journal of Nutrition, Vol. IX (June, 1955), p. 133.

[2] McCloy, Op. Cit.

[3] Frank C. Consolazio, et al., Physiological Measurements of Metabolic Functions in Man (New York: McGraw Hill Book Company, 1963), p. 301.

the average reading was recorded to the nearest 0.1 millimeter.[1] These three assessments were made as rapidly as possible while an assistant recorded the measurements. The technique of measurement was identical for each of the three measurements including regrasping of the skinfold. Every effort was made to measure the same point at each site.[2] All skinfold measurements were made on the right side of the body.[3]

Treatment of the Data

A recording form was developed in order to record information about the subjects as well as measurements. The following information included on this form was: name, social security number, age to nearest birthday, classification in college, major sequence, and the state in which the subject was born. Some measurements were originally recorded in inches because of the nature of the instruments utilized in this study. These measurements include arm span; sitting height; shoulder height,

---

[1] John Piscopo, "Skinfold and Other Anthropometric Measurements of Preadolescent Boys From Three Ethnic Groups," Research Quarterly, Volume XXXIII (May, 1962), p. 257.

[2] Consolazio, Op. Cit.

[3] Ibid.

sitting; buttock-knee length; and knee height, sitting, which were later adjusted and/or converted to the metric system. Weight was recorded in pounds and then converted to kilograms. The Races were coded to indicate obvious visual differentiation as follows: the circle signifies Caucasian; triangle, Negroid; square, Latin American; and the hexagon, for subjects of Oriental extraction.

In order to facilitate the interpretation of the findings the data was computed by the Southern Methodist University Computer Center at Dallas, Texas. An IBM Machine number 360 was used to determine the results of the survey. The IBM Cards were punched by an experienced IBM key punch operator.

The following statistical and/or arithmetical computations were calculated from these data:

1. Number of subjects, mean, range, standard error of the mean, and standard deviation of the thirty-three measurements

2. Multiple correlation matrix of the thirty-two measurements

3. Reciprocal Ponderal Index, which is the height divided by the cube root of the weight

4. Arm span minus biacromial breadth divided by two which is equal to the true arm length

5. Maximal reach minus functional reach

6. Stature minus crotch height with is equal to the true body length

7. Buttock-knee length minus crotch height which is equal to the crotch-buttock length (pelvic depth)

8. Sitting height minus shoulder height, sitting, which is equal to the neck-head length

9. Hip breadth, sitting, minus hip breadth which is equal to the average hip spread when sitting

10. Multiply .55 times stature (inches) which is equal to the center of gravity[1] height from the standing surface

11. Stature divided by crotch height which is equal to the ratio of leg length to true body length

12. Sitting height divided by crotch height which is equal to the ratio of trunk length to leg length

13. The investigator remeasured thirty-nine subjects in order to establish a reliability and the _t_ test for the significance of the reliability was computed for each of the thirty-three measurements.

The details of the statistical program are included in the appendix on pages 112 and 113.

---

[1]Marion R. Broer, _Efficiency of Human Movement_ (Philadelphia: W. B. Saunders Company, 1962), p. 22.

Preparation of the Final Written Report

Upon completion of the presentation, analysis, and interpretation of the data collected, the investigator summarized the report, drew conclusions with respect to the anthropometric survey, and made recommendations for further studies related to this area of research. The investigator also developed a bibliography and compiled an appendix for the investigation.

Summary

In Chapter II the investigator presented a detailed discussion of the procedures followed in the development of this study under the following major headings: Sources of Data, Preliminary Procedures, Procedures for Obtaining Subjects, Description and Techniques of Assessing the Anthropometric Measurements, Treatment of the Data, Preparation of the Final Written Report, and Summary.

Chapter III contains the results of the data collected during the present survey.

CHAPTER III

RESULTS OF THE INVESTIGATION

The findings of the anthropometric investigation are presented in this chapter of the manuscript. For the purposes of simplicity and clarity, the results of the survey, utilizing 1,049 subjects and thirty-three measurements are grouped into tabular form. The summary of individual measurements has been arranged so that closely related anatomical structures are summarized in the same table, and some selected measurements will be discussed in more detail with regard to the implications of the findings in the following chapter. The original findings were recorded in centimeters or millimeters and will be reported and discussed in this unit of measurement. The standard deviation (SD) is in centimeters. The standard error (SE) and the reliability have also been included in these summary sheets. Although 1,049 subjects were originally measured, errors in the recording forms or IBM cards made it possible to analyze data of only 1,010 subjects.

Table 1 tabulates the subjects according to academic year.

TABLE 1

IDENTIFICATION OF SUBJECTS BY ACADEMIC YEAR

Classification		N
Seniors	....	113
Juniors	....	152
Sophomores	....	237
Freshmen	....	547
Total Subjects Measured	....	1049

Measurements of the arms and hands are presented in Table 2. The mean arm span is 165.18 centimeters. The range was found to be from 138.7 to 189.8 centimeters. The mean maximal reach was measured to be 79.56 centimeters with a range from 67.0 to 92.0 centimeters. The average hand span of Texas Woman's University women was found to be 20.20 centimeters and the range was from 16.0 to 23.2 centimeters. The mean hand length was reported to be 17.80 and the range 14.4 to 20.0 centimeters. The average functional reach is 68.39 centimeters and the range, 57.0 to 82.0 centimeters.

TABLE 2

MEASUREMENTS OF THE ARMS AND HANDS[a]

Measurement	Mean Cm.	Range Cm.	SD Cm.	SE Cm.	Reliability[b]
Arm Span	165.18	138.7-189.8	8.16	.2783	.98
Maximal Reach	79.56	67.0-92.0	4.21	.1436	.76
Functional Reach	68.39	57.0-82.0	3.87	.1321	.58
Hand Span	20.20	16.0-23.2	1.94	.0407	.91
Hand Length	17.80	14.4-20.0	0.91	.0310	.93

[a]N = 1010.

[b]Reliability was the Test-Retest method utilizing 39 subjects.

Table 3 describes the measurements of the legs. The mean knee height, sitting, was reported to be 50.22 with a range from 43.0 to 57.0 centimeters. The mean buttock-knee length of 74.39 centimeters was measured and a range from 45.6 to 88.0 centimeters. The mean buttock-leg length was measured at 99.25 centimeters with a range from 86.0 to 114.0 centimeters. The mean crotch height was found to 80.18 centimeters with a range from 70.0 to 91.5 centimeters.

TABLE 3

MEASUREMENTS OF THE LEGS*

Measurement	Mean Cm.	Range Cm.	SD Cm.	SE Cm.	Reliability
Knee Height, Sitting	50.22	43.0-57.0	2.49	.0849	.91
Buttock-knee Length	74.39	45.6-88.0	3.32	.1132	.91
Buttock-leg Length	99.25	86.0-114.0	4.99	.1701	.87
Crotch Height	80.18	70.0-91.5	4.279	.1459	.98

*N = 1010.

Measurements of the body weight and the trunk are presented in Table 4. The average weight of the Texas Woman's University student is 57.36 kilograms. The range for this measurement was from 34.0 to 146.4 kilograms. The mean stature was computed at 163.02 centimeters with a range of 133.2 to 183.2 centimeters. The average shoulder height (which also represents the trunk length) was found to be 57.51 centimeters and a range from 45.5 to 72.6 centimeters. A range from 63.7 to 85.3 was computed for the sitting eye height with a mean of 73.58 centimeters. The average sitting height is 85.99 centimeters. The range is from 60.9 to 98.5 centimeters. The mean waist height, sitting, was found to be 26.0 with a range from 23.0 to 31.5 centimeters.

TABLE 4

MEASUREMENTS RELATED TO BODY WEIGHT AND THE TRUNK[a]

Measurement	Mean Kg.	Range Kg.	SD Kg.	SE Kg.	Reliability
Weight	57.36	34.0-146.4	8.308	.2833	.99
	Cm.	Cm.	Cm.	Cm.	
Stature	163.02	133.2-183.2	6.432	.2193	.99
Shoulder Height, Sitting	57.51	45.5-72.6	2.844	.0970	.90
Eye Height, Sitting	73.58	63.7-85.3	3.270	.1115	.91
Waist Height, Sitting[b]	26.0	23.0-31.5	1.02	.299	.30
Sitting Height	85.99	60.9-98.5	3.505	.1195	.95

[a]N = 1010.

[b]N = 860, the N for this measurement is different because it was added after the measurement program had begun.

The measurements pertaining to circumferences are shown in Table 5. The average biceps circumference is 25.07 centimeters with a range from 17.5 to 43.5 centimeters. The mean knee circumference is 34.03 centimeters with a range from 28.2 to 48.0 centimeters. The average calf circumference is 33.51 centimeters and the range is from 22.5 to 46.0 centimeters. The bust circumference averaged 82.84 centimeters with a range from 69.5 to 114.5 centimeters. The range for the chest circumference of Texas Woman's University women is from 46.5 to 105.0 with an average of 70.85 centimeters, while the mean hip circimference is 91.68 centimeters and a range from 76.0 to 144.5 centimeters. The average waist circumference is 62.77 centimeters and the range is from 55.0 to 100.0 centimeters. The average upper-thigh circumference is 52.51 centimeters and the range is from 39.0 to 80.0 centimeters.

TABLE 5

CIRCUMFERENCE MEASUREMENTS*

Measurement	Mean Cm.	Range Cm.	SD Cm.	SE Cm.	Reliability
Biceps	25.07	17.5-43.5	2.224	.0758	.93
Knee Circumference	34.03	28.2-48.0	2.253	.0768	.87
Calf Circumference	33.51	22.5-46.0	2.463	.0840	.94
Bust Circumference	82.84	69.5-114.5	5.975	.2038	.91
Chest Circumference	70.85	46.5-105.5	5.146	.1755	.85
Waist Circumference	62.77	55.0-100.0	5.367	.1830	.95
Hip Circumference	91.68	76.0-144.5	6.011	.2050	.89
Upper-thigh Circumference	52.51	39.0-80.0	4.558	.1554	.86

*N = 1010.

Depicted in Table 6 are the measurements concerning body breadths. The mean hip breadth, sitting, is 34.52 centimeters with a range from 27.4-52.4 centimeters. The biacromial breadth measured an average of 35.97 centimeters with a range from 28.7 to 42.0 centimeters. An average hip breadth of 32.85 centimeters was recorded with a range from 25.6 to 47.5 centimeters. The mean chest breadth of 25.36 centimeters and a range from 20.2 to 69.5 was recorded. The knee breadth measurement had an average of 9.21 centimeters and a range from 7.5 to 13.1 centimeters. The chest depth had a mean of 18.42 centimeters and a range from 13.5 to 35.0 centimeters.

TABLE 6

MEASUREMENTS OF BODY BREADTH*

Measurement	Mean Cm.	Range Cm.	SD Cm.	SE Cm.	Reliability
Hip Breadth, Sitting	34.52	27.4-52.4	2.76	.0776	.66
Biacromial Breadth	35.97	28.7-42.0	1.652	.0563	.70
Bideltiod Breadth	38.99	33.0-44.3	2.106	.0718	.73
Hip Breadth	32.85	25.6-47.5	2.068	.0705	.90
Chest Breadth	25.36	20.2-69.5	2.375	.0810	.70
Knee Breadth	9.21	7.5-13.1	.821	.0280	.52
Chest Depth	18.42	13.5-35.0	1.656	.0565	.83

*N = 1010.

Table 7 lists the statistical means of the selected anthropometric measurements. The average Reciprocal Ponderal Index was calculated to be 12.98. The true arm length was calculated by subtracting the biacromial breadth from the arm span and dividing by two. This average true arm length is 64.29 centimeters. The maximal reach minus functional reach was found to be 11.27 centimeters. The mean true body length measurement was determined by subtracting the crotch height from the stature and was found to be 82.70 centimeters. The shoulder height, sitting, was subtracted from the sitting height which describes the true neck-head length and is reported to be 29.23 centimeters. The mean hip breadth when sitting was subtracted from the mean hip breadth which describes the mean hip spread, sitting, and which averages 1.67 centimeters. The center of gravity is found to be 90.197 centimeters from the floor or standing surface, and was computed by multiplying the stature (inches) by .55. The ratio of the leg length to the true body length was determined by dividing the stature by the crotch height. This ratio is 2.04. Another ratio, the ratio of trunk length to leg length, was also calculated by dividing the sitting height by the crotch height which averaged 1.10.

TABLE 7

STATISTICAL MEANS OF THE SELECTED ANTHROPOMETRIC MEASUREMENTS*

Item		Mean
1. Reciprocal Ponderal Index	....	12.98
		Cm.
2. True Arm Length	....	64.29
3. Maximal Reach Minus Functional Reach	....	11.27
4. True Body Length	....	82.70
5. Pelvic Depth	....	19.15
6. Neck-Head Length	....	29.23
7. Average Hip Spread when Sitting	....	1.67
8. Center of Gravity Calculated	....	90.197
		Ratio
9. Ratio of Leg Length to True Body Length	....	2.04
10. Ratio of Trunk Length to Leg Length	....	1.10

*N = 1010.

Table 8 shows the correlation coefficient among these thirty-three anthropometric measurements. It is obvious that all of these coefficients cannot be discussed, so only measurements with high values that are related to

Measurements		1	2	
1.	Weight		0.452	
2.	Stature	0.452		
3.	Arm span	0.434	0.789	
4.	Maximal reach	0.444	0.610	
5.	Functional reach	0.422	0.552	
6.	Sitting height	0.375	0.703	
7.	Canthus height, sitting	0.357	0.675	
8.	Shoulder height, sitting	0.382	0.621	
9.	Hip breadth, sitting	0.791	0.282	0
10.	Knee height, sitting	0.484	0.783	
11.	Buttock-leg length	0.468	0.743	
12	Biacromial breadth	0.502	0.435	
13.	Bideltoid breadth	0.716	0.352	
14.	Chest breadth	0.450	0.183	
15.	Hip breadth	0.783	0.356	
16.	Knee breadth	0.601	0.143	
17.	Bust circumference	0.759	0.207	
18.	Chest circumference	0.692	0.166	
19.	Waist circumference	0.761	0.175	
20.	Hip circumference	0.856	0.309	
21.	Crotch height	0.383	0.783	
22.	Upper-thigh circumference	0.814	0.194	
23.	Knee circumference	0.770	0.306	
24.	Calf circumference	0.758	0.270	
25.	Chest depth	0.603	0.182	
26.	Biceps	0.738	0.156	
27.	Buttock-knee length	0.550	0.578	
28.	Hand span	0.353	0.399	
29.	Hand length	0.363	0.560	
30.	Triceps, skinfold	0.529	-0.020	-0
31	Scapula, skinfold	0.561	-0.017	0
32.	Umbilicus, skinfold	0.390	-0.015	

4	5			8	9
0.444	0.422	0.375	.357	0.382	0.791
0.610	0.552	0.703	0.675	0.621	0.282
0.752	0.675	0.402	0.402	0.352	0.242
	0.905	0.281	0.275	0.260	0.284
0.905		0.248	0.247	0.236	0.290
0.281	0.248		0.841	0.807	0.319
0.275	0.247	0.841		0.802	0.331
0.260	0.236	0.807	0.802		0.357
0.284	0.290	0.319	0.331	0.357	
0.624	0.572	0.388	0.354	0.315	0.273
0.606	0.553	0.345	0.326	0.286	0.278
0.456	0.398	0.321	0.295	0.255	0.355
0.304	0.264	0.302	0.298	0.282	0.567
0.150	0.123	0.235	0.233	0.256	0.373
0.278	0.271	0.364	0.355	0.346	0.825
0.145	0.125	0.213	0.186	0.212	0.551
0.240	0.219	0.204	0.201	0.233	0.620
0.164	0.143	0.187	0.179	0.209	0.563
0.224	0.203	0.172	0.159	0.182	0.636
0.298	0.281	0.301	0.280	0.302	0.808
0.649	0.598	0.336	0.327	0.293	0.226
0.234	0.223	0.223	0	0.239	0.746
0.327	0.305	0.269	0	0.276	0.676
0.246	0.230	0.313	0.	0.299	0.615
0.248	0.232	0.182	0	0.221	0.493
0.221	0.202	0.182	0.1	0.203	0.609
0.557	0.510	0.248	0.	0.223	0.403
0.432	0.382	0.282	0.	0.251	0.206
0.634	0.578	0.272	0.	0.266	0.216
0.057	0.053			0.548	0.026
0.135	0.130			0.033	0.462
-0.007	-0.005			0.060	0.375

A 32 X 32 MA

	11	12	13	14	
	0.468	0.502	0.716	0.450	
	0.743	0.435	0.352	0.183	
	0.731	0.525	0.387	0.136	0
	0.606	0.456	0.304	0.150	0
	0.553	0.398	0.264	0.123	
	0.345	0.321	0.302	0.235	0
	0.326	0.295	0.298	0.233	0.3
	0.286	0.255	0.282	0.256	0.
	0.278	0.355	0.567	0.373	0
	0.778	0.414	0.376	0.148	0
		0.417	0.393	0.149	0.
	0.417		0.612	0.284	0.
	0.393	0.612		0.509	0.
	0.149	0.284	0.509		
	0.365	0.380	0.669	0.402	
	0.165	0.262	0.513	0.315	0
	0.256	0.364	0.680	0.509	0.
.	0.215	0.328	0.655	0.493	0.
.236	0.241	0.366	0.661	0.474	0.
.	0.344	0.376	0.613	0.391	0.
	0.780	0.375	0.254	0.078	0.
	0.258	0.336	0.619	0.385	0.
	0.337	0.319	0.502	0.297	0
	0.278	0.346	0.533	0.300	0.
	0.196	0.224	0.400	0.291	0
	0.218	0.336	0.638	0.367	0.
	0.626	0.396	0.383	0.185	
	0.321	0.319	0.242	0.114	.
	0.526	0.406	0.274	0.072	
	0.163		0.450	0.244	0.
	0.068	0.230	0.419	0.281	0.
	0.028	0.116	0.371	0.319	

TABLE 8

BODY DIMENSIONS CORRELATION COEFFICIENTS

16	17	18	19	20	21
0.601	0.759	0.692	0.761	0.856	0.383
0.143	0.207	0.166	0.175	0.309	0.783
0.110	0.200	0.156	0.180	0.280	0.791
0.145	0.240	0.164	0.224	0.298	0.649
0.125	0.219	0.143	0.203	0.281	0.598
0.213	0.204	0.187	0.172	0.301	0.336
0.186	0.201	0.179	0.159	0.280	0.327
0.212	0.233	0.209	0.182	0.302	0.293
0.551	0.620	0.563	0.636	0.808	0.226
0.210	0.243	0.210	0.236	0.346	0.831
0.165	0.256	0.215	0.241	0.344	0.780
0.262	0.364	0.328	0.366	0.376	0.375
0.513	0.680	0.655	0.661	0.613	0.254
0.315	0.509	0.493	0.474	0.391	0.078
0.615	0.626	0.600	0.640	0.806	0.260
	0.545	0.524	0.544	0.625	0.058
0.545		0.813	0.817	0.743	0.146
0.524	0.813		0.770	0.666	0.080
0.544	0.817	0.770		0.770	0.138
0.625	0.743	0.666	0.770		0.257
0.058	0.146	0	0.138	0.257	
0.672	0.737	0	0.771	0.884	0.158
0.710	0.596	0.	0.616	0.757	0.278
0.696	0.589	0	0.602	0.714	0.174
0.467	0.663	0.	0.607	0.568	0.087
0.640	0.691	0.	0.696	0.706	0.095
0.274	0.342	0	0.369	0.500	0.670
0.153	0.194	0.	0.147	0.223	0.363
0.151	0.141		0.144	0.247	0.607
0.523	0	0.	0. 77	0.593	-0.023
0.371	0.	0.	0.	0.588	0.010
0.313	0.	0.	.	0.456	-0.036

	23	24	25	26
	0.770	0.758	0.603	0.738
	0.306	0.270	0.182	0.156
	0.279	0.233	0.142	0.160
234	0.327	0.246	0.248	0.221
223	0.305	0.230	0.232	0.202
223	0.269	0.313	0.182	0.182
	0.257	0.293	0.168	0.178
	0.276	0.299	0.221	0.203
	0.676	0.615	0.493	0.609
	0.377	0.323	0.182	0.191
	0.337	0.278	0.196	0.218
	0.319	0.346	0.224	0.336
	0.502	0.533	0.400	0.638
	0.297	0.300	0.291	0.367
	0.644	0.634	0.482	0.616
	0.710	0.696	0.467	0.640
	0.596	0.589	0.663	0.691
	0.549	0.561	0.603	0.646
	0.616	0.602	0.607	0.696
	0.757	0.714	0.568	0.706
	0.278	0.174	0.087	0.095
	0.743	0.746	0.572	0.771
		0.778	0.487	0.674
	0.778		0.495	0.708
	0.487	0.495		0.573
	0.674	0.708	0.573	
	0.446	0.369	0.283	0.322
	0.285	0.297	0.181	0.213
	0.322	0.259	0.127	0.188
	0.557	0.504	0.437	0.643
	0.472	0.422	0.512	0.554
	0.291	0.258	0.409	0.408

28	29	30		
0.353	0.363	0.529		0
0.399	0.560	-0.020	-0.	
0.463	0.710	-0.033	0.035	
0.432	0.634	0.057	0.135	
0.382	0.578	0.053	0.130	
0.282	0.272	0.034	-0	0
0.279	0.284	0.054	-0.	
0.251	0.266	0.054	0.033	
0.206	0.216	0.548	0.462	0
0.382	0.616	0.026	0.052	
0.321	0.526	0.048	0.068	0
0.319	0.406	0.163	0.230	0
0.242	0.274	0.450	0.419	
0.114	0.072	0.244	0.281	
0.208	0.225	0.544	0.420	0.
0.153	0.151	0.523	0.371	0.
0.194	0.141	0.546	0.619	0.
0.143	0.089	0.497	0.	0.
0.147	0.144	0.577	0.	
0.223	0.247	0.593	0.	
0.363	0.607	-0.023	0.	-0
0.186	0.173	0.645	0.	
0.285	0.322	0.557	0	
0.297	0.259	0.504	0	
0.181	0.127	0.437	0.	
0.213	0.188	0.643	0.	
0.276	0.461	0.182	0	
	0.559	-0.005	0	
0.559		-0.034		
-0.005	-0.034			
0.068	0.046	0		
-0.016	-0.077	0.		

this present investigation will be noted. Garrett[1] emphasizes that coefficients from .40 to .70 are substantially or markedly related while coefficients from .70 to 1.00 are highly to very highly related. The stature is related to the functional reach with a coefficient of .55; shoulder height, .62; maximal reach, .61, and crotch height, .78. The functional arm reach is related to arm span with a coefficient of .67; maximal reach, .91, and crotch height, .60. The shoulder height is related to sitting height with a coefficient of .81 and canthus height, .81. The crotch height shows a relationship with arm span with a coefficient of .79; maximal reach, .65; buttock-leg length, .78, and buttock-knee length, .67. The maximal reach indicates a high correlation with the buttock-leg length, .61; buttock-knee length, .56; and the hand length, .63. The functional reach is correlated highly with the buttock-leg length, .55; a crotch height, .60; buttock-knee length, .51; and hand length, .58. A correlation of .74 is reported for the relationship between buttock-leg length and stature. The buttock-leg length correlates .61 with maximal reach, and .53 with the hand length.

---

[1]Henry E. Garrett, Elementary Statistics (New York: David McKay Company, Inc., 1963), p. 100.

Summary

In Chapter III of this report the investigator has summarized the results of the computer analysis of the anthropometric data. These data are presented in the following manner:

(1) Identification of the Subjects by Academic Year, (2) Measurements of the Arms and Hand, (3) Measurements of the Legs, (4) Measurements Related to Body Weight and the Trunk, (5) Circumferential Measurements, (6) Measurements of Body Breadth, (7) Statistical Means of the Selected Anthropometric Measurements, and (8) A 32 x 32 Matrix of Body Dimensions Correlation Coefficients.

Chapter IV will include an analysis of the findings and a discussion of the implications of these data with certain selected measurements from the anthropometric survey for the teaching of specific physical education skills, namely tennis and golf, and recommendations with respect to the design and construction of athletic equipment for women related to these specific physical education skills.

CHAPTER V

IMPLICATIONS OF THE FINDINGS

Although a vast amount of data was collected in this anthropometric survey, the investigator has limited the discussion of the findings to selected measurements which relate particularly to the sports of golf and tennis. Data not interpreted in this report of the study were collected because important interrelationships may exist between many anatomical measures. These interrelationships are best depicted by the matrix of intercorrelations between such fundamental measures, e.g., arm span, maximal reach, functional reach, crotch height, trunk length. Many body measurements are related to the performances of various athletic skills and may influence such factors as agility, balance, posture, and flexibility. It is not the intention of the investigator to explore all of these facets of motor performance, but to concentrate attention on a few selected measurements and their possible influence upon successful performance in two selected sports.

Implications for Tennis

The present study evolved from the investigator's frequent observations of the marked disparity between the physical characteristics of the participants and the athletic equipment utilized in the performance of specific sports skills. The objective of this investigation was to relate information from a systematic anthropometric survey of university women to the design of selected sports equipment and to identify specific problems that occur in many teaching situations today because of existing equipment or equipment usually available to the teacher.

Tennis involves many complex skills which have a tendency to discourage novices.[1] Students are often expected to begin participating in tennis without any prior experience to familiarize them with the relatively complex skills, strategy, or basic equipment utilized in the game. Elaine Mason, who has taught tennis for twenty years, synthesizes this dilemma as follows:

> A common problem of the beginner is the inability to connect with the ball, and stroke it effectively enough to feel a measure of success. Without early success, many students lose interest in learning to play at all.[2]

The ability to judge spatial and temporal relations are

---

[1]Charles Wolbers, "Move Into Tennis," Journal of Health, Physical Education and Recreation, Vol. XXXIX, No. 4 (April, 1968), p. 23.

[2]Elaine Mason, "New Tennis Progressions," Journal of Health, Physical Education and Recreation, Vol. XXXIX, No. 4 (April, 1968), p. 24.

critical in learning a complex skill such as tennis.

Motion is the predominant ingredient in most sports. It is of vital importance to know the laws which influence force or direct motion if the physical educator or athlete is to produce the most efficient and effective results from the motion which may be developed. Motion of the body *en toto*, the movement of a specific segment of the body, or the movement of an object or implement by the body, requires judicious application of muscular forces, often of a relatively complex nature. Bunn comments "in order to know how to move most effectively one must know the why of movement."[1]

The human body achieves movement and extensibility through a system of levers. Bunn defines a lever as a "mechanical device to produce turning motion about an axis."[2] A lever consists of an axis or fulcrum which is the center or axis of rotation, a power arm or "movement arm"[3] which is the distance from the fulcrum to the point where the force is applied, and a weight arm which is the distance from the fulcrum to the weight upon which

---

[1]John W. Bunn, *Scientific Principles of Coaching* (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1960), p. 5.

[2]*Ibid.*, p. 49.

[3]Katharine F. Wells, *Kinesiology* (Philadelphia: W. B. Saunders Co., 1950), p. 51.

the force acts.

In the human body there are three orders or classes of levers, the class depending upon the position of the fulcrum relative to the force point, and weight concentration or resistance point. A first class lever is a lever system wherein the fulcrum is located between the force point and resistance point. In a second class lever the resistance point is between the fulcrum and the force point. This lever is rarely found in the human body. The third class lever is identified by the force point being applied between the fulcrum and the resistance point.

Gardiner[1] explains that the human body contains more third class levers than any other single type. The third class lever works at a mechanical disadvantage, but <u>is the lever of velocity, having the advantage of speed and range of movement at the sacrifice of force</u>.[2,3] Because speed and range of movement are physically associated and interdependent functions, they are usually discussed in describing the movement of levers.[4] Wells illustrates

---

[1]M. Dena Gardiner, <u>The Principles of Exercise Therapy</u> 3rd Ed. (New York: Macmillan Co., 1963), p. 12.

[2]<u>Ibid</u>.

[3]Wells, <u>Op</u>. <u>Cit</u>., p. 33.

[4]<u>Ibid</u>.

succinctly and graphically this mechanical principle of speed and range. For example, if two third class levers each move through a 40° angle at the same angular velocity, the tip of the longer lever will be traveling faster than the tip of the shorter lever, because it covers the distance in the same time that it takes the tip of the shorter lever to travel across the smaller space.[1] Figure 1 illustrates this mechanical principle with two levers, AB and AC.

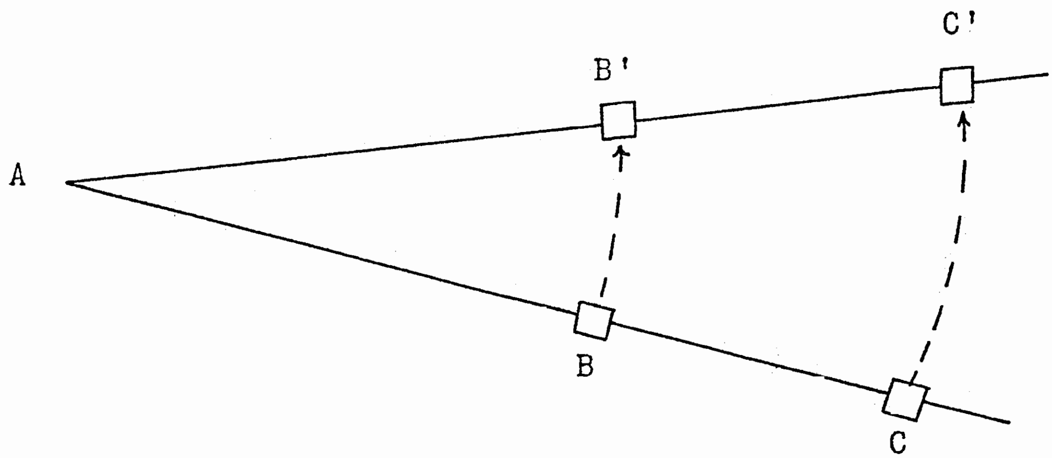


Fig. 1. -- Comparison of Two Levers Moving Through the Same Number of Degrees

The points B and C indicate the weight points of two levers.

---

[1] Ibid., p. 32.

Since C moves to C' in the same length of time it takes B to travel to B', it is obvious that C is moving faster than B. Wells points out that sports implements lengthen the levers of the body and may serve as effective third class levers in themselves or as extensions of the human arm.[1] Wells continues to explain that

> Frequently the sport implement, the arm and a large part of the rest of the body act together as a system of levers.
> ....
> This multiple leverage contributes to one end, namely the speed of the tip of the bat. Sports implements, therefore, may be said to compensate for the limitations of human force.[2]

The movement of stroking a tennis ball involves both linear and circular (angular) motions. The linear movement originates in the forward movement of the body. The circular motion arises from the rotation of the body about the spinal column and the rotation of the striking arm around the glenohumeral articulation. In order to produce the greatest amount of force, the radius of rotation should be as long as possible and the movement should be through as great an arc as possible.

Figure 2, on page 52 depicts this mechanical principle.[3] Bunn reaffirms that

---

[1] Ibid.

[2] Ibid.

[3] Bunn, Op. Cit., p. 243.

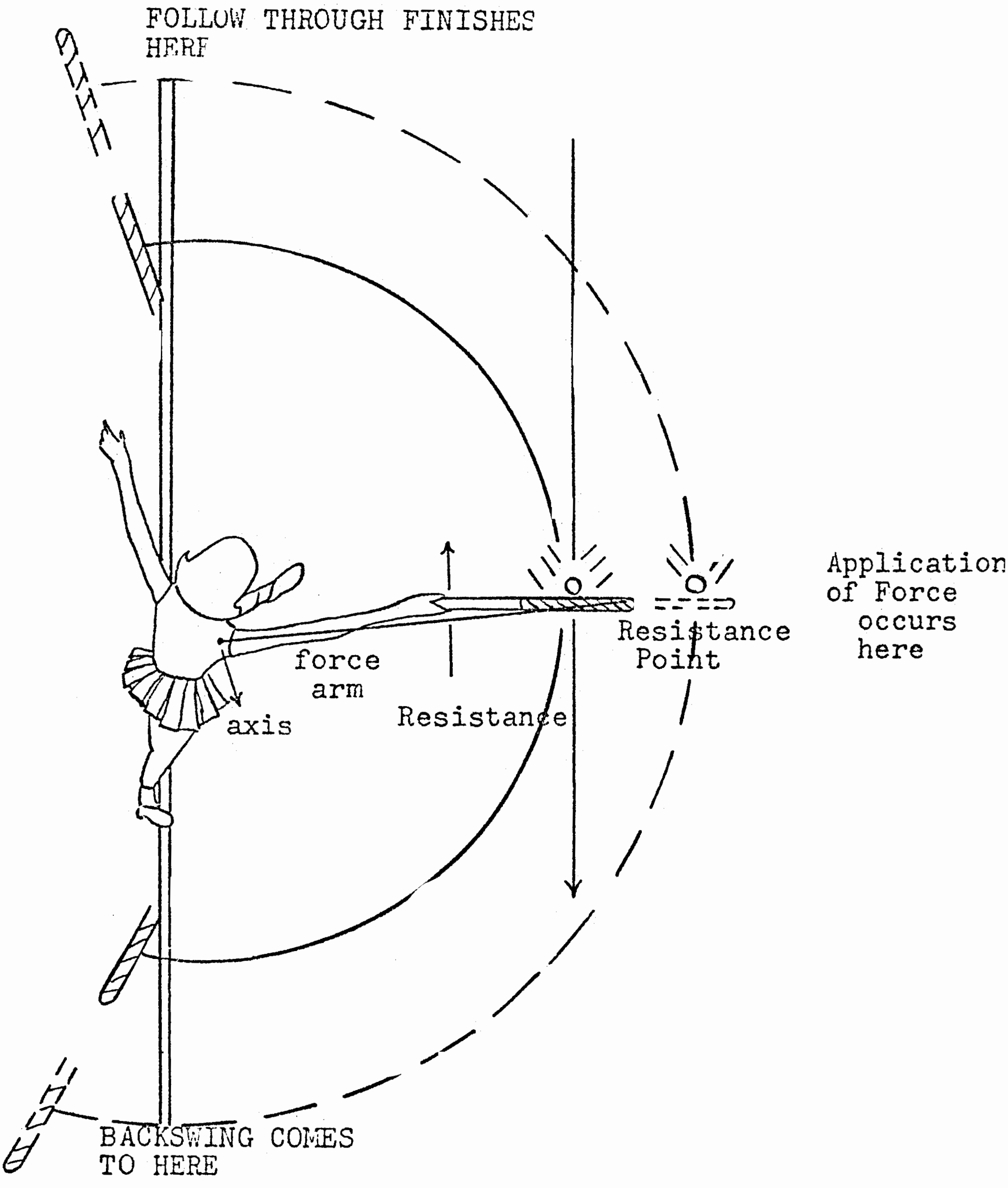


Fig. 2. -- Illustration of the Effect of the Length of the Radius of Rotation Upon Peripheral Velocity of the Racket.

> ... the linear velocity varies directly with the length of the radius when the rotary or angular velocity remains constant. Thus, with a constant angular velocity, if great linear speed is desired, then the radius should be lengthened as much as possible.[1]

Cooper and Glassow point out that the hip lever, because of its possible length of moment arm, may be the major contributor to the forehand drive in tennis.[2] They explain that when the player faces the net as the ball is contacted, the moment arm for hip action will include the width of the pelvis, the length of the arm, and the length of the racket. This overall leverage (moment arm) could possibly be more than six feet in length. Figure 2 illustrates that in order to swing through a large arc, the body is faced at right angles to the intended direction of the flight of the ball. The racket should be drawn back as far as possible on the backswing in order to increase the arc through which it passes, and also to increase the velocity of the racket. This backswing also puts a preliminary stretch on the muscles of the shoulder girdle therefore increasing the ability to apply force while increasing the player's ability to reach the ball.

The data presented in Table 2 on page 35 clearly

---

[1]*Ibid.*, p. 36.

[2]John M. Cooper and Ruth B. Glassow, *Kinesiology* (St. Louis: C. V. Mosby Co.), p. 84.

points out the tremendous differences in the functional reach of tennis players. The functional arm length of two different players, for example, may differ as much as ten inches which would physically result in a difference of peripheral velocity of the racket at its midpoint by as much as seven feet per second (8.7%). This reach difference, illustrated in Figure 2 with broken lines, not only influences the amount of force that can be applied to the ball, but also the capability of the player making contact with the ball. For the purposes of the above mentioned calculation it was assumed that the velocity of the racket was a very moderate fifty feet per second for the player with the shorter arm. It has been estimated that the peripheral velocity of Pancho Gonzales' racket travels at 120 miles per hour (176 ft./sec.). This velocity is not unreasonable in view of the fact that baseball pitchers throw a ball in excess of 100 miles per hour (146 ft./sec.). Thus the above mentioned sample calculations actually depict only the minimal effect upon arm length as a factor in reaching and stroking a tennis ball. Since the force of supporting the tennis racket is directly related to the length of the arm and weight of the racket, a specific fatigue factor also exists with an extra long armed player.

Strength plays a prominent role in many sports activities such as tennis. Charles Wolbers makes this observation about the strength and physical fitness of beginning tennis players

> Too many children still lack arm strength and particular emphasis should be given to the development of arm and wrist strength.
> ....
> Their [youngster's] readiness [for tennis] is seriously impeded by low physical fitness...[1]

Marion Broer alludes to this lack of strength among beginners when she writes, "an understanding of the compensations students are likely to make for lack of strength is extremely important in teaching."[2] Broer cites the example that the beginning right handed tennis student who continually hits to the right may lack sufficient strength in the wrist to withstand the force of the ball against the racket.[3] Hence the student "gives with the wrist", thereby turning the racket face to the right. The teacher as well as the student needs to understand that since the ball hits the racket far from the fulcrum (the shoulder) of the lever involved, the force is greatly magnified! Elaine Mason, originator of the "Shorty" racket recognizes the problem of lack of strength when

---

[1]Wolbers, _Op. Cit._

[2]Broer, _Op. Cit._, p. 14.

[3]_Ibid._

she advocates the use of a racket five inches shorter than the conventional one. She asserts that

> With a shorter lever, the new racket forces the student to use his body more, transfer his weight, "stroke" the ball and follow through more completely.[1]

A simple calculation will show that a woman holding a light weight racket (twelve ounces) must apply a constant force just to hold the racket horizontal. If the weight of the racket is increased by three ounces, the load in the shoulder girdle muscles is increased by approximately nineteen per cent (19%) since the force is calculated by multiplying the length of the force arm times the weight of the racket.

Broer explains the relationship between lack of strength and the ability of the student to compensate, which has important implications for teaching, when she states that a student who performs a tennis drive with his arm drawn in so that the elbow is close to the side, may be compensating for lack of strength.[2] She explains

> Since the impact is taken at the end of a shorter lever, it can be withstood with less strength than when the student reaches for the ball with an extended arm (a longer lever).[3]

---

[1]Elaine Mason, "The New "Shorty" Training Racket," Pamphlet, (Fresno: Fresno State College), p. 1.

[2]Broer, Op. Cit., p. 14. [3]Ibid., pp. 14-15.

The problem of hitting the ball with the elbow close to the body may also be the result of a lack of spatial judgment.[1]

Broer recognizes and illustrates the possible cause of poor spatial judgment when she explains

> Through the years the student has built up a spatial concept of the distance that he can reach. The length of his arm is familiar to him and he can quickly judge how close to approach an object that he wishes to strike with his hand. Is it not possible that, when he is given a tennis racket that lengthens his reach by approximately 24 inches and is expected to make rapid judgments as to how close to approach the ball in order to hit it with an extended arm plus racket, the habit of a lifetime is too strong, and he approaches the ball at his normal striking distance (arm length)? While swinging he finds that he is too close to the ball and draws the elbow toward the body to shorten the reach. In the long run teaching time could be saved if, when a new implement is introduced, some time were taken to help the student gain the new spatial concept. Perhaps some of these problems have arisen because it has been taken for granted that these new spatial concepts are developed immediately and automatically.[2]

An experienced tennis teacher, Elaine Mason, recognized the difficult pedagogical situation with the visual-space-perception factor and offers a remedy to the problem when she writes

> I've taught tennis for 20 years, and found that dozens of other tennis teachers were having difficulties teaching tennis similar to my problem areas. The

---

[1] *Ibid.*, p. 15.

[2] *Ibid.*

> greatest problem seemed to be in the students at the High School and College level learning to adjust to distance. The regular racket seemed to be too much to use effectively. The players would continually over run the oncoming ball. The same students could learn to use a paddle against a wall in a very short period of time. In my final analysis of all the learning problems I felt that there needed to be one more step in progression from the paddle to the regular racket -- hence the "Shorty"[1]

Mason[2] recommends a teaching progression for tennis which includes the handball method, the small wooden paddle, and the short tennis racket, leading up to the regular racket. When the short racket is employed the player is sacrificing some speed and range of movement for ball control, improved stroking and earlier success in the mastery of certain fundamental tennis skills. These above mentioned teaching progressions have been used successfully in teaching students from the elementary grades through college.

The hand grip size itself may play a significant role in force application in tennis. The hand length measurement for this study was taken by measuring from the dactylion to the midpoint on the bistyloid line which connects the styloid process of the radius and the styloid process of the ulna and varies 5.6 centimeters. This range

---

[1]Letter from Elaine Mason, Tennis Teacher at Fresno State College, Fresno, California 93705, March 24, 1968.

[2]Mason, Op. Cit., 1968.

of hand length determines the capacity of the player to grip a sports implement. Dorothy Humiston[1] suggests a four and one half inch and four and five eights grip size for women and the American Association for Health, Physical Education and Recreation recommends, "the player should use as large a grip and as heavy a racket as he can easily handle."[2] Elaine Mason reports that

> The 4 1/2" grip has been very popular for the girls in H. S. and College. They particularly like a grip that feels comfortable, and I have found that many of the students have a much smaller grip size than I would ever have imagined. This has been particularly surprising, because I had the smaller grip size made especially for children.[3]

The mechanical principles reviewed emphasize the need for recognition of anthropometric dissimilarities and the influence of these factors upon teaching progressions which are mechanically, kinesiologically, and pedagogically logical.

Implications for Golf

The game of golf was a popular sport in Scotland

---

[1]Dorothy Humiston and Dorothy Michel, Fundamentals of Sports for Girls and Women (New York: The Ronald Press Co., 1965). p. 190.

[2]Tennis Group Instruction, Joint Committee of United States Lawn Tennis Association and the American Association for Health, Physical Education and Recreation (Washington: American Association for Health, Physical Education and Recreation, 1963), p. 50.

[3]Mason, Op. Cit., 1968.

as early as the fifteenth century. However, the equipment and facilities used in golf today have undergone revolutionary changes in the last seventy-five years. An attempt upon the part of the investigator to obtain detailed scientific information underlying and influencing these changes has been quite futile. More attention, apparently, has been given to appearance, quality, and the physical properties used in the construction of golf implements than has been directed toward designing clubs to fit the wide varieties of human physiques who will ultimately use this equipment.

Stanley and Ross state that the two most important factors to consider in the selection of golf clubs are club length and club weight.[1] These authors of a popular golf book, state that proper length is dictated by two variables - how tall the golfer is and how far the golfer stands from the ball in the address position.[2] They also emphasize that the length of clubs may vary according to the length of the arms and whether or not the swing is flat or upright.[3] Louise

---

[1]Dave Stanley and George Ross, The Golfers Own Book (New York: Lantern Press, 1956), p. 16.

[2]*Ibid*.

[3]*Ibid*.

Suggs, a famous professional golfer, adds that the most important determining factor in club selection is one's height.[1] An article appearing in Golf Digest however, disagrees with the above mentioned authorities with respect to stature affecting the length of shafts and states

> ... the length of club you use is dependent not upon your height, but upon two other factors: your strength and the length of your arms.[2]

Jack Nicklaus and Victor East point out that a tall golfer's hands fall at almost the same distance from the standing surface as a shorter golfer's hands[3,4] Mr. East, Editorial Assistant of Golf Digest, a popular golf magazine, develops this point of the relationship between stature and club length in further detail. For example, a person five feet, six inches tall may have hands the same distance from the floor as a person six feet, six inches tall. Although in actuality one is taller than the other, the differences in the lengths of their clubs will not be so noticeable. The length of clubs is determined from a hands-to-ground distance, and in these two individuals

---

[1]Louise Suggs, et al., Golf For Women (New York: Doubleday & Co., 1960), p. 22.

[2]"How to Pick Clubs that Fit," Golf Digest, Reprint, South Norwalk, Connecticut.

[3]Jack Nicklaus, "It Isn't a Game of Inches," Sports Illustrated, (May 8, 1967), p. 62.

[4]Victor J. East, Better Golf in 5 Minutes (New Jersey: Prentice-Hall, Inc., 1956), p. 23.

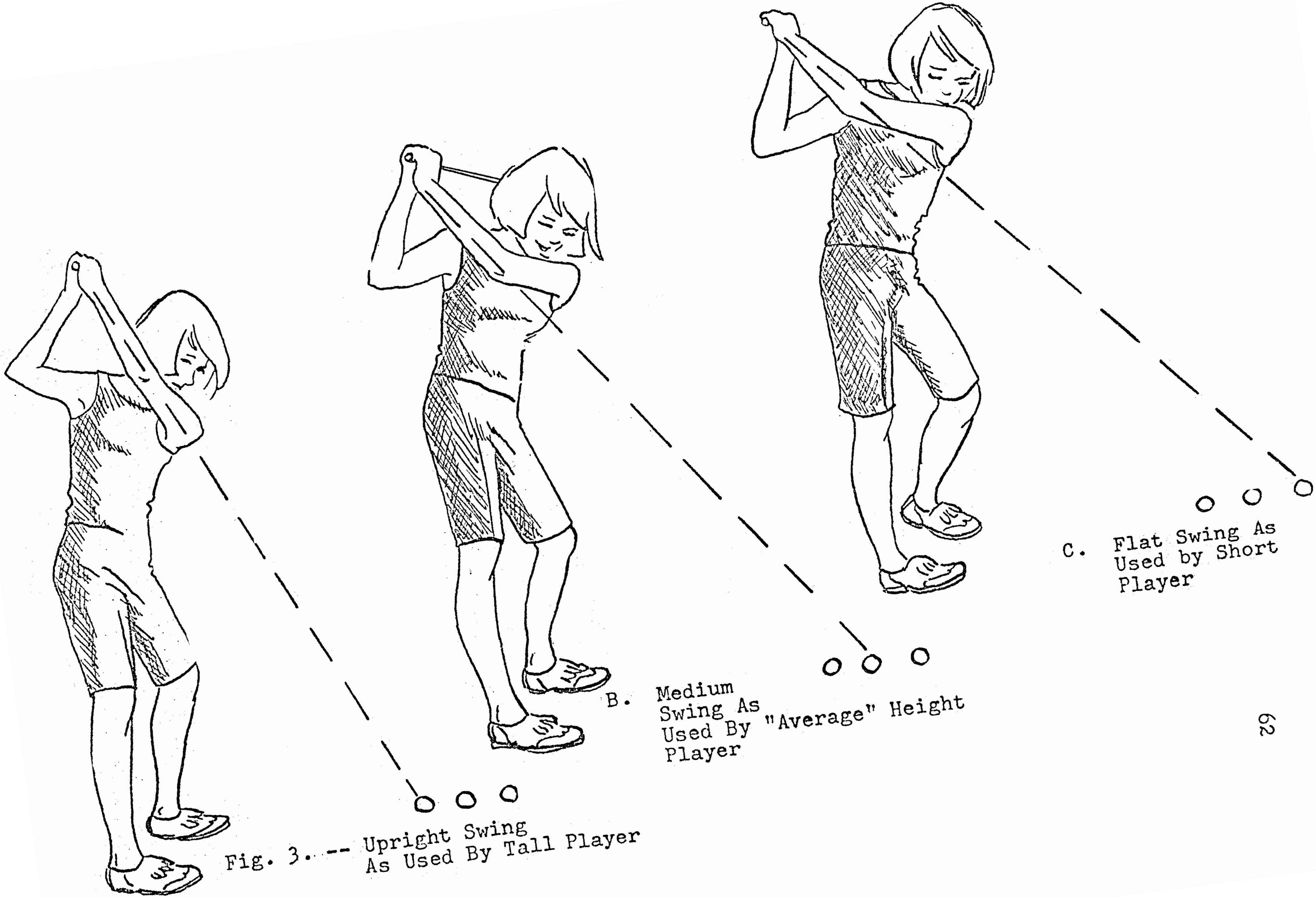


Fig. 3. -- Upright Swing As Used By Tall Player

B. Medium Swing As Used By "Average" Height Player

C. Flat Swing As Used by Short Player

that difference will not exceed a couple of inches. Figure 3 on page 62 illustrates that a tall person may employ an upright swing and therefore take shorter clubs because he is standing closer to the ball. A person of medium stature may stand farther away from the ball than the tall person, as depicted in Figure 3. A short player might have long clubs because she stands fairly far away from the ball and takes a flat swing as shown in Figure 3.

How "average" is the "average" golfer? Pedersen, of Pedersen Sales Company points out that

> ... less than one person out of eight will be "average" even in this highly "average" sample. Or, to put it another way, seven people out of every eight in this group will require some special consideration in design in order to be properly outfitted for their complete wardrobe.[1]

Daniels and Churchill studied the meaning of the "average man".[2] The following information challenges this concept of "average".

> The meaning of average. Machines should not be designed to the concept of the "average man". Average dimensions, by themselves, do not describe any individual. Daniel and Churchill set out to find how many men in a group of 4063 flight personnel were within $\pm$ 15% of the averages of ten different dimensions used in clothing design. As the following

---

[1]Pedersen Sales Company, The Proper Fit (Connecticut: Pedersen Sales Company, 1966), p. 4.

[2]G. S. Daniels and Edmund Churchill, The "Average Man"? WRCD TN 53-7, (Wright Air Development Center, Wright-Patterson Air Force Base, Ohio: December, 1952).

table shows, not one of the 4000 - odd men showed values within the middle 30% in all ten dimensions: as the percentages show, very few showed more than three or four of them.[1]

		Per Cent of Original Sample
(1)	Of the original 4063 men, 1055 were of approximately average stature	25.9
(2)	Of these 1055 men, 302 were also of approximately average chest circumferences	7.4
(3)	Of these 302 men, 143 were also of approximately average sleeve length	3.5
(4)	Of these 143 men, 73 were also of approximately average crotch height	1.8
(5)	Of these 73 men, 28 were also of approximately average torso circumference	.69
(6)	Of these 28 men, 12 were also of approximately average hip circumference	.29
(7)	Of these 12 men, 6 were also of approximately average neck circumference	.14
(8)	Of these 6 men, 3 were also of approximately average waist circumference	.07
(9)	Of these 3 men, 2 were also of approximately average thigh circumference	.04
(10)	Of these 2 men, 0 were also of approximately average crotch length	.00[2]

The concept of the "average" girl is equally misleading and has little meaning since Daniels and Churchill have shown that the probability that one person is average

---

[1]Paul Webb (ed.) Bioastronautics Data Book (Ohio: Prepared under contract for NASA by Webb Associates, Yellow Springs, Ohio, Scientific and Technical Information Division, National Aeronautics and Space Administration, Washington, D. C., 1964), p. 242.

[2]H. T. E. Hertzberg, Some Contributions of Applied Physical Anthropology to Human Engineering (Ohio: WADD TR 60-19, Wright Air Development Division, Wright-Patterson Air Force Base, January, 1960).

in more than four physical characteristics is approximately ninety-nine to one. One must consider, therefore, not the "average" girl, but what the writer will refer to as the <u>composite</u> girl, resulting from the computer analysis of these anthropometric data. This "composite" Texas Woman's University girl has been calculated to be five feet four inches tall, one hundred twenty-five pounds, with a true arm length of twenty-five inches, biacromial breadth of fourteen inches, trunk length of twenty-two inches, a crotch height of thirty-two inches, and head - neck length of eleven and forty-nine hundredths inches. For comparative purposes, a diagram has been drawn to scale in Figure 4 page 66 to illustrate the "composite" girl, in broken lines, as contrasted with the minimal and maximal girl, solid lines. This drawing was constructed utilizing the means and ranges of the various basic measurements. Notice particularly the difference between the top of the head of the "composite" girl and the top of the head of the maximal girl. This difference between the shortest girl and the "composite" girl is (30 Centimeters) twelve inches, and the range from shortest to tallest is as much as twenty inches (50 Centimeters). It is readily evident that there exist a vast range of difference in these scaled figures if one considers just height alone.

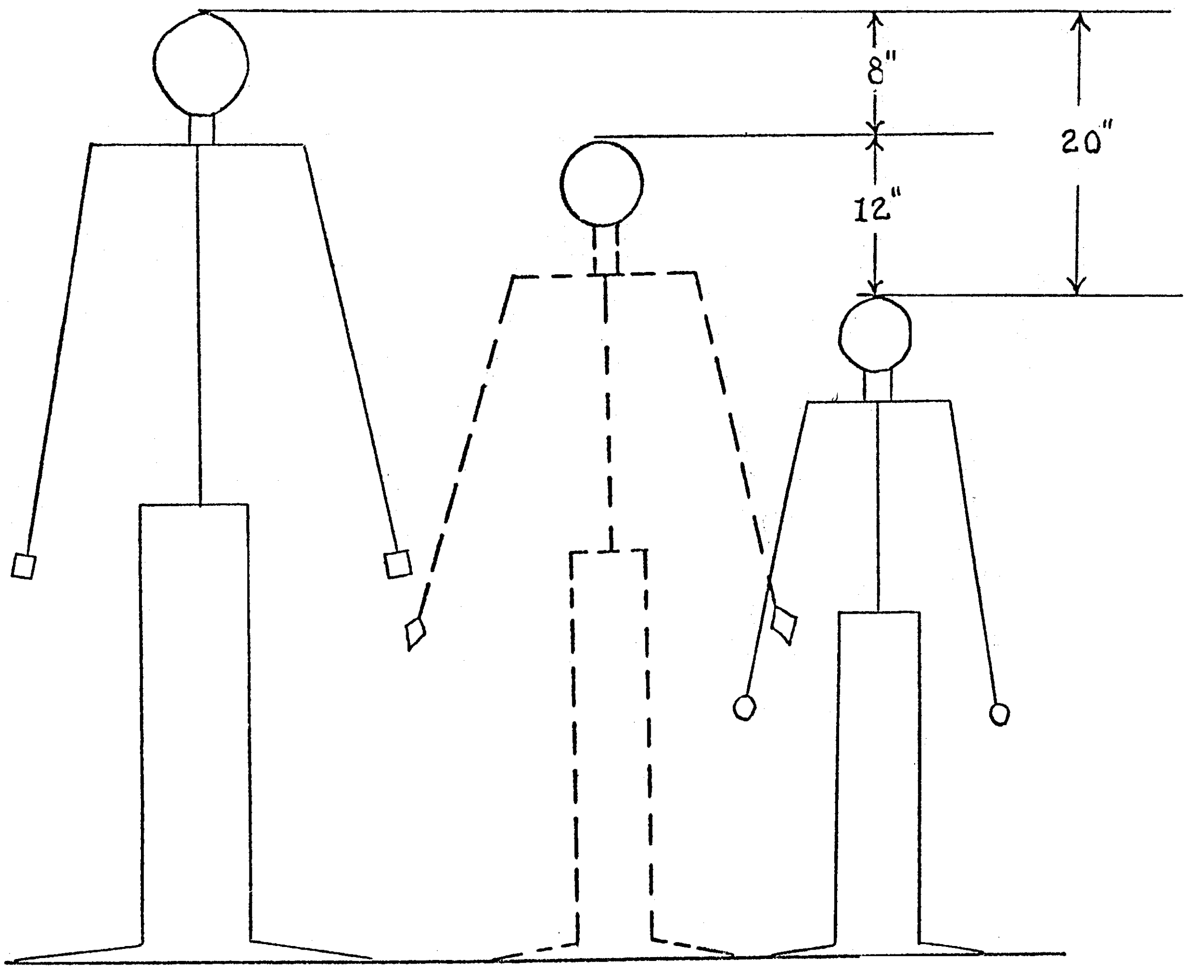


Fig. 4. -- "Composite Girl," Broken Lines,
Diagrammed From Computer Means,
and Maximal and Minimal Ranges
of Basic Body Dimensions

Athletic equipment manufacturers are making equipment to fit this "composite", often called "average" girl, who does not really exist! Manufacturers are therefore making equipment for non-existent persons and expecting the maximal and minimal size person to adjust mechanically despite anthropometric distortions. Not only do the tallest and shortest students have major problems adjusting to this equipment that is mass produced but all persons between these extremes must contend with these equipment disparities.

In Figure 5, on page 68, another illustration has been drawn to scale to demonstrate the effect that the wide ranges in body build has upon the players' ability to meet the golf ball with an implement designed only for the "average" woman. The "composite" girl in the center of the figure was drawn utilizing the means of the computed data. The position of the feet, body posture, and club length were held constant. This figure clearly illustrates the dilemma of the golf teacher who must of necessity use equipment made for the nonexistent "average" girl. It is obvious that the small or above "average" woman could only meet the ball in the proper manner by altering the posture or substituting a club whose length is fitted to her physique. It is clearly evident that golf clubs which are manufactured in mass production should be made in three different lengths

Fig. 5. -- Physique Dissimilarities and Their Effect Upon the Player's Ability to Strike the Golf Ball Correctly

to accomodate the wide range of physiques.

Golfers accept, without question, the specifications of the No. 2 iron they cannot "handle", instead of seeking out modifications that can be applied to make the club a usable one.[1] Mr. Pedersen illustrates this problem of ill-fitted clubs when he notes

> the average golfer - <u>who needs the help</u> - is depriving himself of the accepted and readily available equipment aids that tournament professionals and other fine players insist upon.[2]

This problem of selection of clubs among amateurs seems to result from a lack of basic knowledge with respect to golf equipment or the mechanics of golf. The manufacturers of golf clubs face this dilemma with designing clubs for the "average" golfer because of individual differences in any given population. Ben Hogan adds, with respect to the length of shafts, that

> Making any set rule on the length of weight of the driver for you to use, without fitting it to your individual needs, would be an error. The old golf instructional theory used to be that a short man should use a short club and a tall man should use a long club, but students of the game have come to realize that the reverse is nearer to the correct theory.

---

[1]Pedersen, *Op. Cit.*, p. 2.

[2]*Ibid*.

> For instance, Bobby Cruickshank, who is only slightly more than five feet in height and is always referred to as "The Wee Scot," used a driver with a 44-inch shaft.[1]

If golf clubs are not properly fitted to the participant, the game, of necessity, will have to be adjusted - consciously or unconsciously - to fit the clubs, and the participant will have to play in a most unnatural manner. How can a golfer expect to hit the ball straight with imperfectly made clubs?

Bobby Jones, a distinguished golf authority, suggests that any uncomfortable posture in the address position will produce a strain somewhere which will cause the ensuing movement to be jerkey.[2] Jones further notes that it is easy to see that if the swing is adjusted to strike the ball in a certain position, even a slight variation in the address will cause an error in hitting.[3] Jones continues that the amateur golfer does not swing smoothly because at some stage in his swing he creates a condition that makes it easier for him to move in the

---

[1]Ben Hogan, Ben Hogan's Power Golf (Abridged Edition: Louisville, Kentucky: Fawcett Publications, Inc., 1948), p. 16.

[2]Bobby Jones, Bobby Jones On Golf (New York: Doubleday & Co., 1966), p. 24.

[3]*Ibid*., p. 36.

wrong direction than in the right one.[1] He then emphasizes that most golfers lose sight of the fact that in the address position it is ease and comfort that are to be sought, and that a strained or unnatural position has never been recommended by anyone.[2]

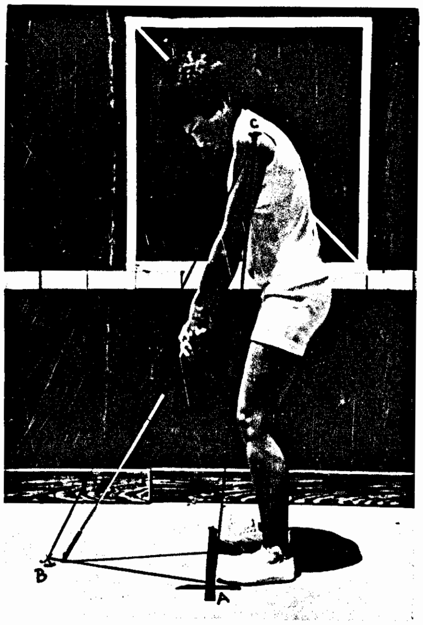
The following photographs illustrate the changes in posture of the address position with varying club lengths. In Plate I the subject, who is five feet and five inches tall is holding a No. 5 iron, which is thirty-six inches in length and a proper fit for her height. A triangle has been superimposed upon the picture to illustrate the change in body posture of the address position when the subject changes from a short No. 5 iron to a longer No. 5 iron. Two variables, the position of the feet, and the position of the golf ball, were held constant. The acromion process was identified by a black mark. The distance from the ball to the black line in these illustrations is eighteen and three fourths inches.

---

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

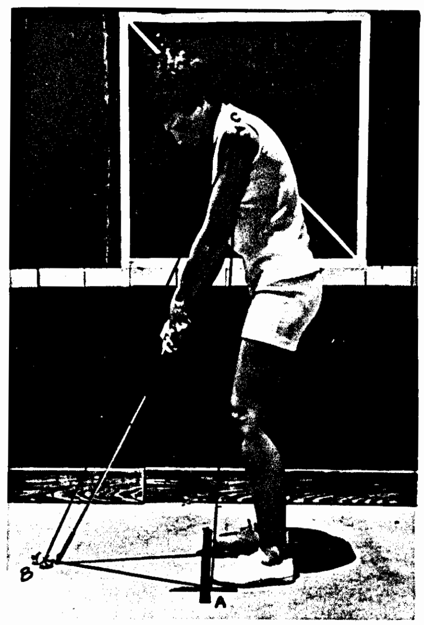
[2] *Ibid.*, p. 20.

PLATE I



SUBJECT HOLDING NO. 5 IRON THIRTY-SIX INCHES IN LENGTH

PLATE II



SUBJECT HOLDING NO. 5 IRON THIRTY-FIVE AND ONE HALF INCHES IN LENGTH

In Plate I line BC was measured and found to be 6.2 millimeters in length in the finished picture. Line BC in Plate II is 6.3 millimeters in length because the club length is different and the posture of the subject has been altered merely by changing the length of the equipment. Attention is called to the position of the head of the subject in Plate II in relation to the line in the background, which in indicative of reaching for the ball. Louise Suggs warns that

> The most important precaution to observe is to avoid reaching for the ball. This is a very common fault. In reaching for the ball you destroy balance, comfort, and the relaxed feeling so important to a good golf swing.[1]

Jones agrees with Suggs when he discusses body position in addressing the ball and emphasizes that to lean over and reach for the ball has two other effects on the posture that are detrimental to the golf swing. First, reaching produces a tension in the muscles of the forearms; and secondly, the excessive bend at the waist lessens considerably the player's ability to freely turn his hips. The golfer bends low over the ball and stretches out until he can reach to a distance he thinks will enable him to hit the ball. The bending at the waist and the reaching are both damaging to the swing, but the restricting of the hips is by far the worst fault, because it is in the use of the muscles in the waist and back that the amateur golfer is most deficient. In this reach position there is a complete restriction of the muscles which make it impossible for him to relax after the swing gets under way. Reaching for the ball also forces the golfer to have a flatter swing arc, thus cutting down on the ability of

---

[1]Louise Suggs, Par Golf For Women (New York: Prentice-Hall, Inc., 1953), p. 22.

the golfer to apply additional velocity (force) to the club head.[1]

The player who reaches out for the ball gets into trouble because he cannot extend his arms and still remain relaxed. The extreme of reaching is often seen in the player who extends his arms and elevates his hands until arms, hands, and club complete a straight line from his shoulders to the ball. The left arm and the club should lie in the same vertical plane but no one in his wildest moments ever conceived that they should lie in the same plane in any other direction. Jones sums up the reaching problem when he states that "the important fact is that the more erect posture makes it easier for all members and muscles of the body to cooperate in a smooth and powerful stroke.[2] Arnold Palmer adds that

> many amateurs seem to want to make the golf swing harder than it is; they stand too far from the ball, which makes them crouch and bend too far. (Or maybe it's that they crouch too far, which makes them stand too far from the ball). At any rate, you see far more people standing bent too far over the ball than standing too erect. This throws their weight forward onto the balls of their feet and gets them completely off-balance.[3]

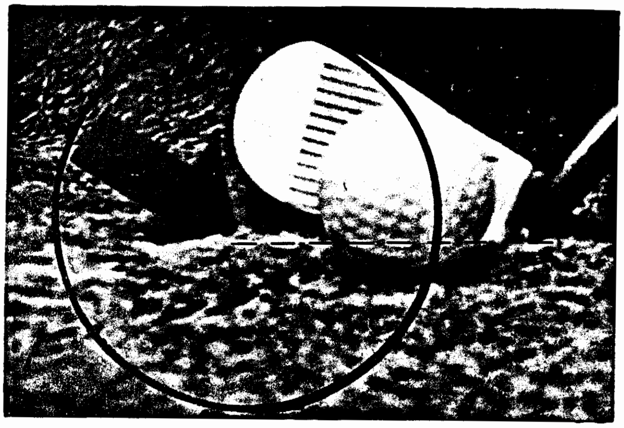
---

[1]Jones, _Op_. _Cit_., pp. 34-35.

[2]_Ibid_., p. 35.

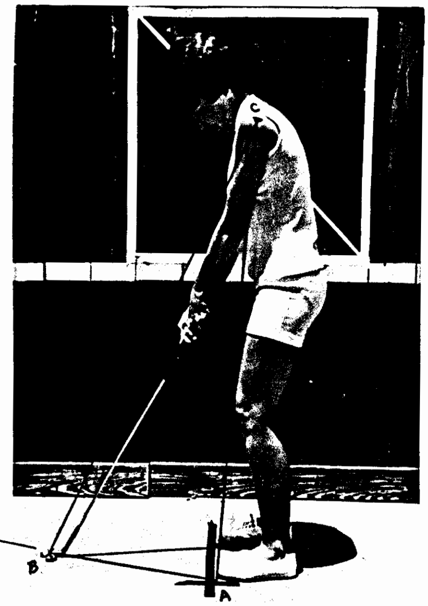
[3]Arnold Palmer, _My Game and Yours_ (New York: Simon and Schuster, Inc., 1965), p. 28.

PLATE III



CLOSE-UP OF CLUB HEAD SOLED INCORRECTLY AS INDICATED WITH THE ARROW

PLATE IV



SUBJECT HOLDING NO. 5 IRON THIRTY-SEVEN INCHES IN LENGTH

In Plate IV the subject is utilizing a No. 5 iron which is thirty-seven inches in length. Line BC is six and nine tenths millimeters in length which is longer than line BC in Plate I and II. This subject is assuming a more erect posture. The forward head position is approximately the same as in Plate I with respect to the vertical line in the background, but the body is more erect. This erect or upright posture would of necessity make the subject's arc more upright, require a longer club, and make it necessary to stand closer to the ball, as was suggested by East and illustrated in Figure 3 on page 62.

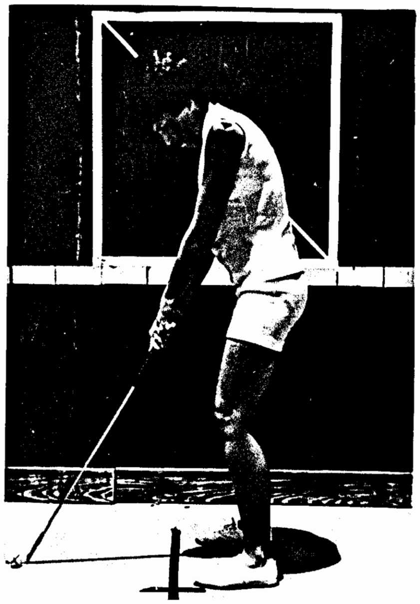
If a long club is utilized by a golfer of medium height as Plate IV illustrates, there is a tendency for the club head to be soled incorrectly, that is, the toe of the club is lifted too far off of the ground. Note the close up of the club head in Plate III. Victor East points this out when he explains that the bottom edge of the club is the sight for aiming - it must go through the line which is perpendicular to the direction one wishes the ball to travel. The club head travels at ground level at and after impact in the line of direction desired. Every motion that takes place in the golf swing is designed and aimed toward one thing - to take the face of the club "through" the ball ...[1] This correct procedure described by East is not likely to take place if the club head is not soled correctly.

In Plate V the subject was given a long club and asked to adjust her posture to the ball which remained in the same place when she used the proper club. Attention

---

[1]East, _Op_. _Cit_., p. 11.

PLATE V



SUBJECT ADJUSTED FEET TO NO. 5
IRON WHICH IS THIRTY-SEVEN INCHES
IN LENGTH

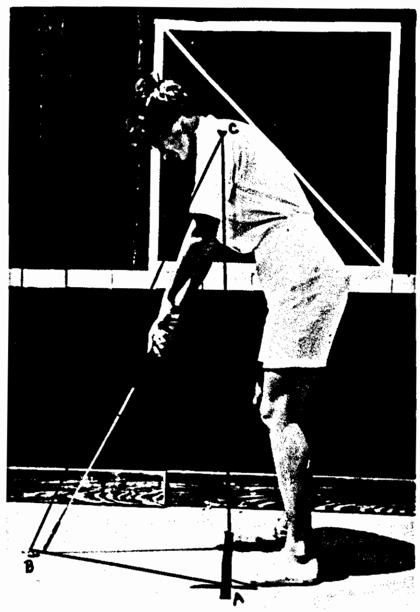
is brought to the distance of the subject's feet from the ball and the black line that is used for a reference point. In this illustration the subject is standing twenty-three and one half inches from the ball as opposed to eighteen and three fourths inches for the properly fitted club. Byron Nelson makes this point about golfers who stand too far from the ball

The player who stands too far from the ball encourages a flat swing arc. His shoulders will not go high enough on the backswing. The clubhead moves too much around the body and not enough up and over the shoulders. With a too-flat swing, it is easy to roll the clubface over into a closed position on the downswing. The result is a low shot that often also hooks badly to the left.[1]

PLATE VI

TALL SUBJECT HOLDING NO. 5 IRON THIRTY-SEVEN INCHES IN LENGTH

PLATE VII



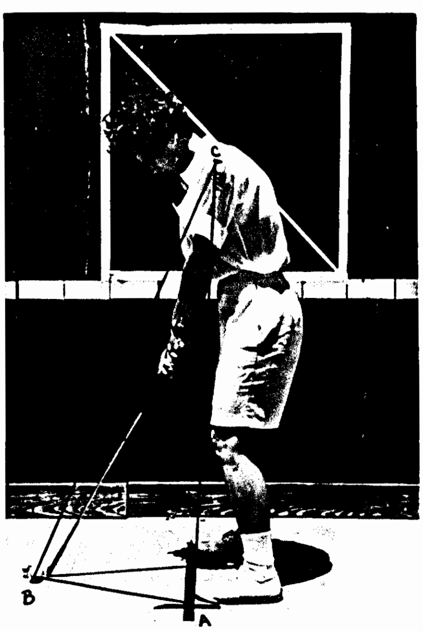
TALL SUBJECT HOLDING NO. 5 IRON THIRTY-SIX INCHES IN LENGTH

---

[1]Byron Nelson, <u>Golfer's Digest</u>, Delux Edition, Vol. II. John May (ed.) "Proven Remedies for Grass Cutting,' (Chicago: Follett Publishing Co.), p. 150.

The remaining illustrations, Plates VI, VII, VIII and IX are of subjects five feet and seven inches tall and five feet and three inches tall, respectively. The same problems with club lengths, body posture and teaching the proper swing is illustrated in these photographs as was illustrated in the foregoing discussion and illustrations.

PLATE VIII



SHORT SUBJECT HOLDING NO. 5 IRON THIRTY-FIVE AND ONE FOURTH INCHES IN LENGTH

PLATE IX

SHORT SUBJECT HOLDING NO. 5 IRON THIRTY-SEVEN INCHES IN LENGTH

Summary

A pedagogical and learning hinderance arises in many situations today because of individual anthropometric dissimilarities among students with respect to available athletic equipment. These problems are clearly understood in light of the application of fundamental mechanical principles. The writer reviewed several principles of physics and applied these knowledges to the problems of teaching and participation in tennis and golf. Through the use of these mechanical principles it was demonstrated how improperly fitted golf clubs and tennis rackets affect the participant's performance in regard to posture, compensation for lack of strength, ability to apply force, controlled flight of the ball, and the ability to judge spatial relations and timing. The point was discussed that golf clubs, manufactured in mass production mehtods, are made for the "average" golfer although, no such person exists. Several examples were presented to show how a player may compensate for equipment which she or he is not able to "handle". Photographs of subjects of different heights and authoritative documentation were presented to illustrate the change in posture with varying lengths of golf clubs, which may influence the golfer's capacity to strike the ball effectively.

Chapter V will include a Summary of the Survey, the Conclusions drawn according to the results of the analysis of the data, and Recommendations for Future Studies.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE STUDIES

This chapter includes a summary of the survey, conclusions based upon the findings, and recommendations for future studies.

Summary of the Survey

Anthropometry is a tool which can be utilized with varying degrees of effectiveness in solving certain problems which arise in physical education, however it is no more an end in itself than is a microscope. The value of work in bacteriology depends upon the quality of the microscope, so does the solution of certain fundamental problems in human biology often referred to as "dynamic anthropometry". Scientific methods only manifest their superiority when one seeks out the more subtle relationships such as are encountered in the dynamics of human movement.

Such factors as safety, comfort, conservation of energy, and human efficiency are all ultimately related directly or indirectly to the body type characteristics or the physical proportions of an individual. Through anthropometric techniques, one may obtain quantitative information which can be subjected to other objective analytical techniques, e.g., physical mechanical or kinesiological analyses.

The application of anthropometric data may take many forms depending upon whether one seeks to treat movement as whole or concentrate on more specific anatomical measurements such as structures or the ratios of levers to body structures such as the trunk. The nature of the problem may in many instances dictate the interrelationships to be examined.

This study was originally conceived as an investigation concerned with the fundamentals of body kinematics and it has in no way been dominated by a search for quick empirical or *ad hoc* answers to practical questions. Nevertheless the composite girl and the range of her potential activity and anatomical relationships have been focal. Such a view of relationships is without meaning unless it can in some way contribute to an understanding of the ways in which human beings behave. This in turn, should contribute to practical ends.

Kinematic and mechanical information on the system of the body should provide the behavioral picture with respect to structure and form. If the kinematic and mechanical aspects of the body are pursued far enough, they can contribute a great deal of usable information to the field of physical education.

One of the fundamental objectives of physical education is to provide knowledges of the structure and function of the human body which are fundamental to the understanding and solution of movement problems. These knowledges of structure can be obtained only through anthropometric surveys and ultimately by mathematical computer analysis of date collected in such studies.

In the present anthropometric survey, 1,049 college age women were measured utilizing thirty-three measurements. These measurements were analyzed on an IBM computer. The investigator was able to determine the composite (average) subject as contrasted with the maximal or minimal size girl. These data pertaining to selected body proportions were used to illustrate the many pedagogical problems which may be encountered in a class of golf or tennis. A simple mechanical analysis of several aspects of golf and tennis was made which depicted the dilemma of the students with dissimilar physiques who must of necessity use the same athletic equipment designed for the nonexistent "average" girl. Photographs were presented to illustrate graphically the major problems the student would encounter while using equipment which does not fit properly.

Statement of the Problem

This study comprised an intensive anthropometric measurement program encompassing 1,049 women enrolled in the Texas Woman's University during the academic year of 1967-1968. A systematic investigation was conducted that concentrated upon the critical examination of selected anthropometric measurements which have scientific, as well as practical, implications for the teaching of the golf swing and tennis stroke and the selection and design of athletic equipment for women.

Purposes of the Study

The general purposes of this study are:

1. To provide valuable anthropometric information which may have implications for the teaching of golf and tennis skills to undergraduate college women.

2. To provide authoritative anthropometric measurements of undergraduate college women for utilization by manufacturers of selected items of golf and tennis equipment for women.

Conclusions of the Findings

Based upon the data collected and analyzed, the following conclusions appear to be warranted as a result of this investigation:

1. To permit the most efficient use of athletic equipment employing the human component, it must be designed and constructed to accommodate a wide latitude of body dimensions, which are often overlooked.

2. The designing of athletic equipment for the "average" individual is fundamentally an unsound procedure.

3. Because of individual differences, golf clubs

and tennis rackets should be manufactured, in mass, in at least three different lengths and/or weights.

4. Because of the lack of properly fitted equipment, poor posture results when the student compensates for this inadequacy in equipment design which in turn affects the student's capacity to apply power (force) and to achieve his or her potential in that particular sport.

5. As a result of these compensations on the part of the student, many pedagogical problems arise, several of which have been illustrated.

6. Not only do pedagogical problems develop because of ill fitted equipment, but also learning problems develop on the part of the student.

Recommendations for Future Studies

This investigation could not hope to use all of the data collected in this survey. Many opportunities exist for other investigators to utilize these data collected in this anthropometric study. The findings of this survey have questions for the investigator which brought about the following recommendations for future anthropometric studies.

1. Indicate growth trends in college women in relation to physical education costume design and construction.

2. Provide authoritative anthropometric measurements of college women for the purpose of appraising the contemporary female physique.

3. Provide basic data for the design of automobile seats with implications for driver safety.

4. Provide data pertaining to fundamental body type which may have implications for general health and incidence of certain types of diseases.

5. Encourage further research in regard to the design of athletic equipment, other than golf and tennis.

6. Provide fundamental statistical data which may be utilized in future long term (longitudinal) studies in relation to physical fitness (performance capacity appraisal), morbidity, health, longevity, and mortality of college women.

BIBLIOGRAPHY

BIBLIOGRAPHY

Books

Bayer, Leona M. and Bayler, Nancy. Growth Diagnosis. Chicago: University of Chicago Press, 1959.

Broer, Marion R. Efficiency of Human Movement. Philadelphia: W. B. Saunders Co., 1962.

Brožek, Josef (ed.). Body Measurements and Human Nutrition. Michigan: Wayne University Press, 1956.

Bunn, John W. Scientific Principles of Coaching. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1960.

Consolazio, Frank C., and Others. Physiological Measurements of Metabolic Functions in Man. New York: McGraw Hill Book Company, 1963.

Cooper, John M. and Glassow, Ruth B. Kinesiology. St. Louis: C. V. Mosby Company, 1963.

Cureton, T. K., and Others. Physical Fitness Appraisal and Guidance. "Appraisal of Body Type as an Approach to Health and Physical Guidance," St. Louis: C. V. Mosby Company, 1947.

________. Physical Fitness of Champion Athletes. Urbana: University of Illinois Press, 1951.

Draper, George. Disease and the Man. London: Kegan Paul, 1930.

________. Dupertuis, C. W. and Caughley, J. L. Jr. Human Constitution in Clinical Medicine. New York: Paul B. Hoeber Inc., 1944.

Dublin, Louis Israel. Factbook on Man From Birth to Death. 2nd ed. New York: Macmillan Company, 1965.

________. Lotka, Alfred J., and Speigelman, Mortimer. Length of Life. New York: Ronald Press, 1949.

East, J. Victor. Better Golf in 5 Minutes. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1956.

Franzen, R. Physical Measures of Growth and Nutrition. New York: American Child Health Association, 1929.

Gardiner, M. Dena. The Principles of Exercise Therapy. 3rd ed. New York: Macmillan Co., 1963.

Garrett, Henry E. Elementary Statistics. 2nd ed. New York: David McKay Co., Inc. 1963.

Goldwait, Joel E., Brown, L. T. Swain, L. T. and Kuhns, J. Body Mechanics in the Study and Treatment of Disease. Philadelphia: J. B. Lippincott Co., 1934.

Harris, J. A., Jackson, C. M., Paterson, D. G., and Scammon, R. E. The Measurement of Man. Minneapolis: The University of Minnesota Press, 1930.

Hogan, Ben. Ben Hogan's Power Golf. Abridged Edition. Louisville, Kentucky: Fawcett Publications, Inc., 1948.

Hrdlička, Aleš. Anthropometry. Philadelphia: Wistar Institute of Anatomy and Biology, 1920.

__________. Practical Anthropometry. Philadelphia: Wistar Institute of Anatomy and Biology, 1939.

Humiston, Dorothy and Michel, Dorothy. Fundamentals of Sports for Girls and Women. New York: The Ronald Press Co., 1965.

Jones, Robert Tyre (Bobby). Bobby Jones On Golf. New York: Doubleday and Co., 1966.

Keys, A. Body Measurements and Human Nutrition. Josef Brožek (ed.) "Recommendations Concerning Body Measurements for the Characterization of Nutritional Status," Detroit: Wayne State University Press, 1956.

Kretschmer, E. Physique and Character. Translated from the second revision and enl. ed. by W. J. Sprott. New York: Harcourt, Brace, 1926.

McCloy, C. H. Appraising Physical Status; Methods and Norms. Studies in Child Welfare, Vol. XV, No. 2, Iowa City: University of Iowa, 1938.

__________. Appraising Physical Status: the Selection of Measurements. Studies in Child Welfare, Vol. XII, No. 2, Iowa City: University of Iowa, 1936.

McFarland, and Others. Human body Size and Capabilities in the Design and Construction of Vehicular Equipment. Boston: Harvard School of Public Health, 1953.

McNemar, Quinn. Psychological Statistics. 3rd ed. New York: John Wiley and Sons, Inc., 1962.

Meredith, Howard V. The Rhythm of Physical Growth. Studies in Child Welfare, Vol. XI No. 3, Iowa City: University of Iowa, 1935.

Montagu, Ashley M. A Handbook of Anthropometry. Springfield: Charles Thomas, 1960.

Murray, H. A. Golf Secret. New York: Emerson Books, Inc., 1954.

Nelson, Byron. Golfer's Digest. Delux Edition, Vol. II, John May (ed.) "Proven Remedies for Grass Cutting," Chicago: Follett Publishing Company.

O'Brien, R., and Shelton, W. C. Women's Measurements for Garment and Pattern Construction. Miscellaneous Publication No. 454, Washington, D. C: United States Department of Agriculture in Cooperation With the W.P.A., 1941.

Ohlson, Margaret A., and Others. Body Measurements and Human Nutrition. Josef Brožek (ed.) "Anthropometry and Nutritional Status of Adult Women," Detroit: Wayne State University Press, 1956.

Palmer, Arnold. My Game and Yours. New York: Simon and Schuster, Inc., 1965.

Parnell, R. W. Behavior and Physique. London: Edward Arnold Ltd., 1958.

Pearl, R. Constitution and Health. London: Kegan Paul, Trench and Trubner, 1933.

Seaver, J. W. Anthropometry and Physical Examination. New Haven, Connecticut: Curtiss-Way Company, 1909.

Sheldon, W. H., Stevens, S. S., and Tucker, W. B. Varieties of Human Physique. New York: Harper and Brothers, 1940.

Sports Illustrated. Tips From the Top. Vol. 2. Compiled by Herbert Warren Wind and illustrated by Anthony Ravielli. Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1956.

Stanley, Dave and Ross, George. (eds.) The Golfers Own Book. New York: Lantern Press, 1956.

Suggs, Louise, and Others. Golf For Women. New York: Doubleday and Company, 1960.

________. Par Golf for Women. New York: Prentice-Hall, Inc., 1953.

Tennis Group Instruction. Joint Committee of United States Lawn Tennis Association and the American Association For Health, Physical Education and Recreation, Washington: American Association For Health, Physical Education and Recreation, 1963.

Wells, Katherine F. Kinesiology. Philadelphia: W. B. Saunders Company, 1950.

Wilder, H. H. A Laboratory Manual of Anthropometry. Philadelphia: P. Blakiston's Son and Company, 1920.

Articles

Angel, J. L. "Constitution in Female Obesity," American Journal of Physical Anthropology, n.s., Vol. VII, (1949), pp. 433-471.

Baker, P. T., Hunt, E. E. and Sen. Tulika. "The Growth and Interrelations of Skinfold and Brachial Tissues in Man," American Journal of Physical Anthropology, Vol. XVI (March, 1958), pp. 39-55.

Barker, Roger and Stone, Calvin P. "Growth in Height and Weight in College and University Women," Science, Vol. LXXXIII (January 17, 1936), pp. 59-61.

Bayer, L. M. "Hand Size in Working Women," Human Biology, Vol. VIII (1936), pp. 267-272.

________. and Gray, H. "The Hand: Method of Measurement," American Journal of Physical Anthropology, Vol. XVII (1933), pp. 379-415.

"Body Conformation, Coronary Heart Disease and Longevity," Nutritional Review, Vol. XXV (January, 1967), pp. 5-6.

Bookwalter, Karl W. "The Relationship of Body Size and Shape to Physical Performance," Research Quarterly, Vol. XXIII (October, 1952), pp. 271-279.

Breitinger, Emil. "Body Form and Athletic Achievement of Youths," Research Quarterly, Vol. VI (May, 1936), pp. 85-91.

Brožek, Josef. "Quantitative Description of Body Composition: Physical Anthropology's "Fourth Dimension," Current Anthropology, Vol. IV (1963), pp. 3-39.

________. and Keys, A. "The Evaluation of Leanness-Fatness in Man: Norms and Interrelationships," British Journal of Nutrition, Vol. V (1951), pp. 194-206.

Burchard, E. M. "Physique and Psychosis; An Analysis of the Postulated Relationship Between Bodily Constitution and Mental Disease Syndrome," Comparative Psychology Monographs, Vol. XIII (1936), pp. 1-73.

Campbell, J. K. "The Relation of the Type of Physique to the Type of Mental Disease," Journal of Abnormal and Social Psychology, Vol. XXVII (1932), p. 147-151.

Chenoweth, L. B. "Increase in Height and Weight and Decrease in Age of College Freshmen Over a Period of 20 Years," Journal of American Medical Association, Vol. CVIII (1937), pp. 354-356.

Ciocco, Antonio. "Height of Body in Adults. Survey of Differences in Methods of Measuring, Instruments, and Classifications," American Journal of Physical Anthropology, Vol. XXII (1936), pp. 141-151.

________. "Sitting Height and Sitting Height: Stature Index in Adults. Survey of Differences in Methods of Measuring, Instruments and Classifications," American Journal of Physical Anthropology, Vol. XXII (April-June, 1937), pp. 467-475.

Count, Earl W. "Statement of General Objectives," Annals of the New York Academy of Sciences, Vol. LXIII, Art. 4 (November 28, 1955), pp. 435-441.

Craig, Margaret B. A. "Comparison of Five Methods Designed to Predict the "Normal" Weight of College Women," Research Quarterly, Vol. XV (March, 1944), pp. 64-74.

Cureton, T. K. "Body Build as a Framework of Reference for Interpreting Physical Fitness and Athletic Performance," Research Quarterly, Vol. XII (May, 1941), pp. 301-330.

Damon, Albert. "Notes on Anthropometric Technique II. Skinfolds - Right and Left Sides: Held by One or Two Hands," American Journal of Physical Anthropology, Vol. XXIII (September, 1965), pp. 305-311.

Davenport, C. B. "Some Principles of Anthropometry," American Journal of Physical Anthropology, Vol. XXIII, No. 1 (July-September, 1937), pp. 91-99.

Dempster, Wilfrid Taylor. "The Anthropometry of Body Action," Annals of the New York Academy of Sciences, Vol. LXIII, Art. 4 (November 28, 1955), pp. 559-585.

Donelson, E. G., Ohlson, M. A., Kunerth, B., Patton, M. Brown, and Kinsman, G. M. "Anthropometric Data on College Women of the Middle States," American Journal of Physical Anthropology, Vol. XXVII (1940), pp. 319-332.

Dupertuis, C. W. "Anthropometry of Extreme Somatotypes," American Journal of Physical Anthropology, n.s. Vol. VIII, No. 3 (1950), pp. 367-383.

Edwards, D. A. W. and Others. "Design and Accuracy of Calipers for Measuring Subcutaneous Tissue Thickness," British Journal of Nutrition, Vol. IX (June, 1955), pp. 133-143.

________. "Observations on the Distribution of Subcutaneous Fat," Clinical Science, Vol. IX (1950), pp. 259-270.

Elftman, Herbert. "Body Dynamics and Dynamic Anthropometry," Annals of the New York Academy of Sciences, Vol. LXIII, Art. 4 (November 28, 1955), pp. 553-558.

Ethredge, Maude and Lopold, Judah. "A Study of Age, Weight, and Height of Entering Freshmen at the University of Illinois," Research Quarterly, Vol. XI (March, 1940), pp. 142-143.

Fletcher, R. F. "The Measurement of Total Body Fat With Skinfold Calipers," Clinical Science, Vol. XXII (1962), pp. 333-346.

Fry, E. I. "The Measurement of Subcutaneous Tissue by the Harpenden Caliper and by Surgical Incision," American Journal of Physical Anthropology, Vol. XIX (1961), p. 98.

Garn, S. M. "Fat Weight and Fat Placement in the Female," Science, Vol. CXXV (1957), pp. 1091-1092.

"How to Pick Clubs That Fit," Golf Digest, Reprint, South Norwalk, Connecticut.

Howells, W. W. "Some Uses of the Standard Deviation in Anthropometry," Human Biology, Vol VIII (December, 1936), pp. 592-600.

Husband, R. W. "Body Build and Personality Traits in College Students," Journal of General Psychology, Vol. XVIII (January, 1938), pp. 199-201.

Huxley, Aldous. "Who Are You?" Harper's Magazine, No. 1134, (November, 1944), pp. 512-522.

Jackson, C. M. "Physical Measurements of the Female Students at the University of Minnesota With Special Reference to Body Build and Vital Capacity,' American Journal of Physical Anthropology, Vol. XII (1929), pp. 363-408.

James, T. F. "The American Housewife," Cosmopolitan, (January, 1958), pp. 20-47.

Jensen, K. "Growth, Anthropometric Measurements," Review of Educational Research, Vol. XXII (December, 1952), pp. 397-398.

________. "Physical Growth," Review of Educational Research Vol. XXV (December, 1955), pp. 369-414.

Jorgenson, N. W. and Hatlestad, S. Lucille. "Determination and Measurement of Body Build in Men and Women College Students," Research Quarterly, Vol. XI (December, 1940), pp. 60-77.

King, B. G. "Measurements of Man For Making Machinery," American Journal of Physical Anthropology, Vol. VI (1948), pp. 341-351.

Krakower, Hyman. "Anthropometry: A Brief Survey of the Measurement of Man - From Ancient Civilization to 1932," Research Quarterly, Vol. VIII (October, 1937), pp. 85-95.

Krogman, Wilton Marion. "The Historical Aspect of the Study of Human Constitutional Types." Cibia Symposia. George Rosen (ed.) Summit, New Jersey: Cibia Pharameceutical Products Inc., (1941), pp. 1058-1088.

Marshall, Everett L. "The Objectivity of Anthropometric Measurements Taken on Eight-and Nine-Year-Old White Males," Child Development, Vol. VIII (1937), pp. 249-256.

Mason, Elaine. "New Tennis Progressions," Journal of Health, Physical Education and Recreation, Vol. XXXIX, No. 4, (April, 1968), p. 24.

McCloy, C. H. "Anthropometry in the Service of the Individual," Journal of Health, Physical Education and Recreation, (September, 1934), pp. 7-11.

Meredith, Howard V. "The Reliability of Anthropometric Measurements Taken On Eight-and Nine-Year-Old White Males," Child Development, Vol. VII (December, 1936), pp. 262-272.

________. "Techniques of Research in Physical Growth and Anthropometry," Review of Educational Research, Vol. XIX (1939), pp. 80-87.

Mills, C. A. "Is the Human Growth Tide Turning?" Human Biology, Vol. X (December, 1938), pp. 547-554.

Mohr. G. J. and Gundlach, R. H. "The Relation Between Physique and Performance," Journal of Experimental Psychology, Vol. X (1927), pp. 117-157.

Molitch, M. "Body Build Factor in Basal Metabolism of Boys," American Journal of Diseases of Children, Vol. L (1935), pp. 621-625.

Montoye, H. J., Epstein, F. H., and Kjelsberg, M. O. "The Measurement of Body Fatness," American Journal of Clinical Nutrition, Vol. XVI (1965), pp. 417-427.

Moore, William M. "Human Growth in Secular Perspective," Postgraduate Medicine (July, 1966), pp. A-89-A94.

Mosher, C. D. "Some of the Casual Factors in Increased Weight of College Women," Journal of American Medical Association, Vol. LXXXI (1923), pp. 535-538.

Nicklaus, Jack. "It Isn't a Game of Inches," Sports Illustrated, (May 8, 1967), p. 62.

Parnell, R. W. "Somatotyping by Physical Anthropometry," American Journal of Physical Anthropology, Vol. XII (1954), pp. 209-239.

Pere, Soini, Kunnas, Mikko and Telkkä, Anti. "Correlation Between Performance and Physique in Finnish Athletes," American Journal of Physical Anthropology, Vol. XII (June, 1954), pp. 201-208.

Peterson, W. F. "Constitution and Disease," Physiological Reviews, Vol. XII (April, 1932), pp. 283-308.

Piscopo, John. "Skinfold and Other Anthropometric Measurements of Preadolescent Boys From Three Ethnic Groups," Research Quarterly, Vol. XXXIII (May, 1962), pp. 255-264.

Powell, A. T. "Percentiles for Evaluation of Body Measurements by College Students," Journal of Home Economics, Vol. LVIII (December, 1966), pp. 792-794.

Pryor, Helen B. "Charts of Normal Body Measurements and Revised Width-Weight Tables in Graphic Form," Journal of Pediatrics, Vol. CXVIII (April, 1966), pp. 615-631.

Sargent, Dudley A. "Physical Development of Women" Scriber's Magazine, (February, 1889), pp. 172-185.

________. "Physical Proportions of Typical Man," Scriber's Magazine, (July, 1887), pp. 3-17.

Seltzer, Carl C. "Anthropometric Characteristics and Physical Fitness," Research Quarterly, Vol. XVII (March, 1946), pp. 10-20.

________. and Mayer, Jean. "Body Build and Obesity -- Who are the Obese?" Journal of the American Medical Association, Vol. LCXXXIX (August, 1964), pp. 677-684.

________. "Body Measurements in Relation to Disease," Postgraduate Medicine, Vol, XXXX (October, 1966), pp. A107-A111.

Škerlj, B., Brožek, Josef, and Hunt E. E. Jr. "Subcutaneous Fat and Age Changes in Body Build and Body Form in Women," American Journal of Physical Anthropology, n.s. Vol. XI (1953), pp. 577-600.

Sloan, A. W., Burt, J. J., and Blyth, C. S. "Estimation of Body Fat in Young Women," Journal of Applied Physiology, Vol. XVII (November, 1962), pp. 967-970.

Steggerda, J., Crane, J., and Steele, M. D. "One Hundred Measurements and Observations On One Hundred Smith College Students," American Journal of Physical Anthropology, Vol. XIII (1929), pp. 189-254.

Tanner, J. M. and Whitehouse, R. A. "The Harpenden Skinfold Caliper," American Journal of Physical Anthropology, Vol. XIII (December, 1955), pp. 743-746.

________. "Earlier Maturation in Man," Scientific American, Vol. LLXVIII (January, 1968), pp. 21-27.

Thompson, Clem W., and Others. "Changes in Body Fat, Estimated From Skinfold Measurements of Varsity College Football Players During a Season," Research Quarterly, Vol. XXX (1959), pp. 87-93.

________. "Changes in Body Fat, Estimated From Skinfold Measurements of College Basketball and Hockey Players During a Season," Research Quarterly, Vol. XXVII (1956), pp. 418-430.

Turner, Abby H. "Body Weights Optimal for Young Adult Women," Research Quarterly, Vol. XIV (October, 1943), pp. 255-276.

Wertheimer, F. I. and Hesketh, Florence E. "The Significance of the Physical Constitution in Mental Disease," Medicine, Vol. V (1926), p. 375.

Willgoose, Carle, and Rogers, Millard R. "Relationship of Somototype to Physical Fitness," Journal of Educational Research, Vol. XXXXII (May, 1949), pp. 704-712.

Williams, Jesse Ferring. "Physique and Health," American Journal of Public Health, Vol. XXVIII (April, 1938), pp. 487-490.

Wilson, Ira and Wilson, Wanda B. "Symetrical Proportion Charts for the Adult Female Body." Research Quarterly, Vol. XI (December, 1940), pp. 3-9.

Wolbers, Charles. "Move Into Tennis," Journal of Health, Physical Education and Recreation, Vol. XXXIX, No. 4 (April, 1968), p. 23.

Young, C. M. and Others. "Body Composition in Young Women Some Preliminary Findings," Journal of American Dietetic Association, Vol. XXXVIII (1961), pp. 332-339.

_________ and Blondin, Joan. "Estimating Body Weight and Fatness of Young Women," Journal of American Dietetic Association, Vol. XXXXI (November, 1962), pp. 452-455.

Reports and Bulletins

Bean, R. B. "Morbidity and Morphology." John Hopkins Hospital Bulletin. Vol. XXIII (1912), p. 363.

Daniels, G. G., and Churchill, Edmund. The "Average Man"? WCRD TN 53-7, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio: December, 1952.

_________ Meyers, H. D., and Churchill E. Anthropometry of Male Basic Trainees WADC Technical Report, 53-49, Wright-Patterson Air Force Base, Ohio: Wright-Patterson Air Force Base, 1953.

Dublin, Louis, and Marks, Herbert. "The Build of Women and Its Relation to Their Mortality." The Association of Life Insurance Medical Directors of America, 1938.

Hertzberg, H. T. E. Some Contributions of Applied Physical Anthropology to Human Engineering. WADD TR 60-19, Wright Air Development Division, Ohio: Wright-Patterson Air Force Base, January, 1960.

_________. The Anthropometry of Flying Personnel WADC Technical Report, 52-321, Wright Air Development Center, Ohio: Wright-Patterson Air Force Base, 1950.

IBM. System/360 Scientific Subroutine Package (360A-CM-03X) Version II, Vol. H20-0205-2. Programmer's Manual, 3rd ed., IBM Publisher (1967).

Mason, Elaine. "The New "Shorty" Training Racket," Pamphlet Fresno: Fresno State College.

Metropolitan Life Insurance Company. "American Women Getting Thinner." Statistical Bulletin Metropolitan Life Insurance Company, 1939.

Narragansett Gymnasium Equipment Catalogue. Moberly, Missouri: Narragansett Gymnasium Equipment Company, 110 West Carpenter Street, 1965.

Pedersen Sales Company. The Proper Fit. Wilton, Connecticut: Pedersen Sales Company, (1966), pp. 3-23.

Van Cott, Harold P., and Altman, James W. Procedures for Including Human Engineering Factors in the Development of Weapon Systems WADC Technical Report, 56-488, AD-97305, Wright Air Development Center Air Research and Development Command, United States Air Force, Ohio: Wright-Patterson Air Force Base, 1956.

Webb, Paul (ed.). Bioastronautics Data Book. Prepared under contract for NASA by Webb Associates, Yellow Springs Ohio, Scientific and Technical Information Division, National Aeronautics and Space Administration, Washington, D. C., 1964.

Unpublished Material

Adam, Marylou Merkel. "Secular Trends in Women's Body Proportions." Unpublished Master's thesis, Pennsylvania State University, 1959.

Blackinton, Marion. "The Values of a Height-Weight Classification Plan as a Predictor of the Motor Ability of College Women." Unpublished Doctoral dissertation, University of Utah, 1965.

Bremberg, Charlene E. "A Study to Determine the Relationship of Certain Anthropometrical Motor Ability, and Reaction-Movement Measurements of High School Girls, Unpublished Master's thesis, Department of Education, Northern Illinois University, 1965.

Hatlestad, Stella. "The Determination and Measurement of Body Build in College Women." Unpublished Master's thesis, University of Iowa, 1940.

Johnson, Marion M. "A Study of Certain Skeletal Dimensions to Body Weight in 1030 Women College Age." Unpublished Master's Thesis, Wellesley College, 1924.

Other Sources

Letter from Josef Brožek, Department of Psychology Lehigh University, Bethlehem, Pennsylvania, November 8, 1967.

Letter from C. Wesley Dupertuis, Professor of Clinical Anthropology, Eugene McDermott Laboratory of Clinical Anthropology, Cleveland, Ohio, December 4, 1967.

Letter from H. T. E. Hertzberg, Research Physical Anthropologist, Department of the Air Force, 6570th Aerospace Medical Research Laboratories (AFSC) Wright-Patterson Air Force Base, Ohio, 45433, June 24, 1968.

Martin, Mrs. C. B. Furnished the Art Work. 4511 13th Street, Lubbock, Texas.

Letter from Elaine Mason, Tennis Teacher at Fresno State College, Fresno, California 93705, March 24, 1968.

Personal Interview with Byron Nelson, Professional Golfer, Roanoke, Texas, June 8, 1968.

APPENDIX A

RECORDING FORM

NAME________________________ STATE BORN IN______________

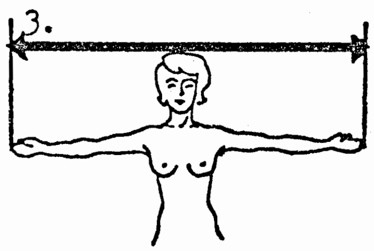
SOCIAL SECURITY NO.________________________

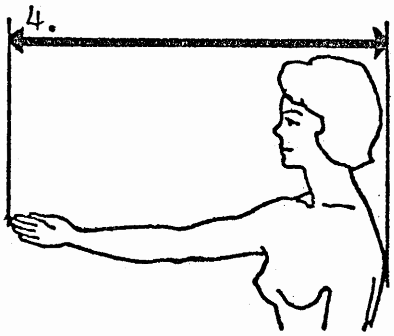
AGE TO NEAREST BIRTHDAY____________________

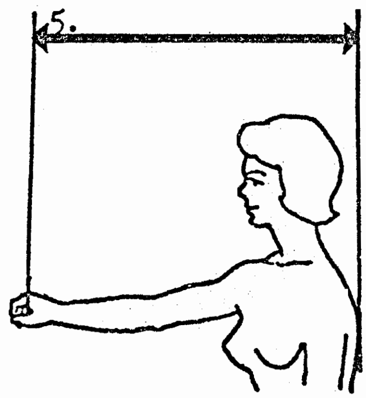
CLASSIFICATION____________________________

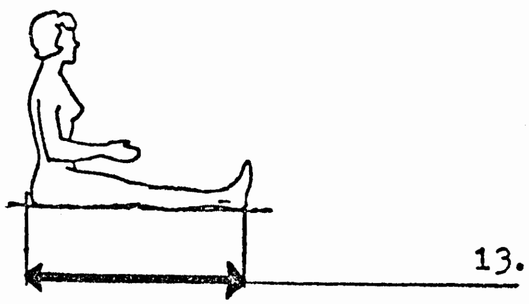
MAJOR SEQUENCE____________________________

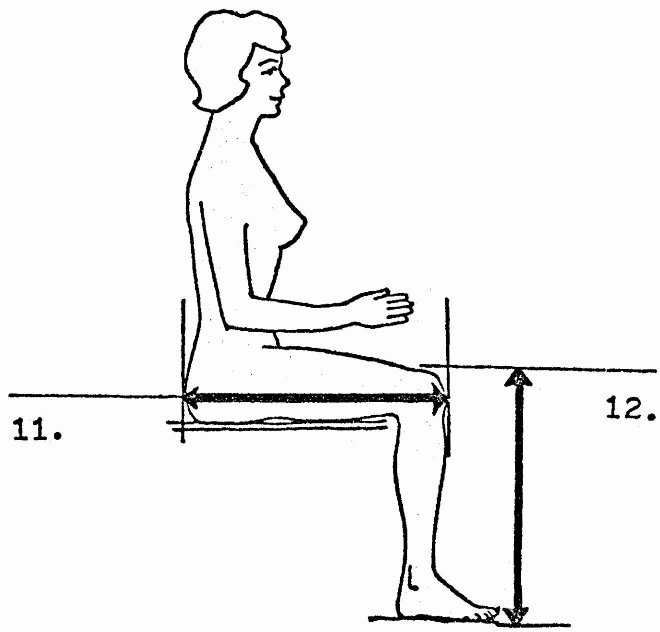
WEIGHT_________________ 1. STATURE_________________ 2.

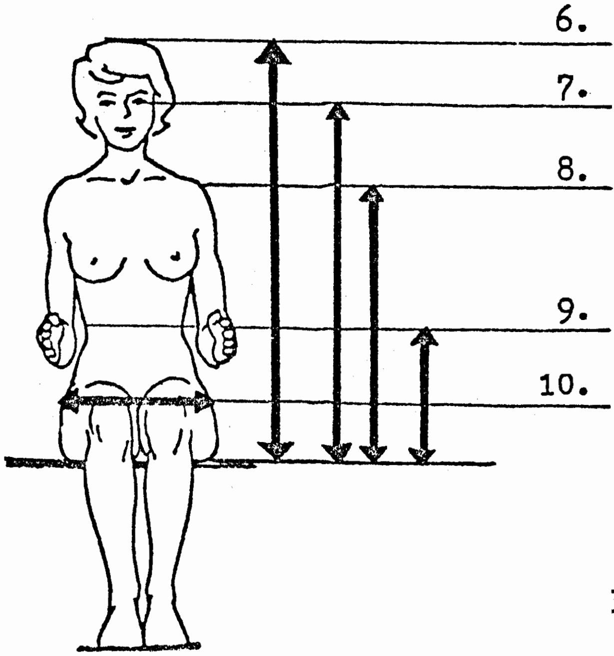






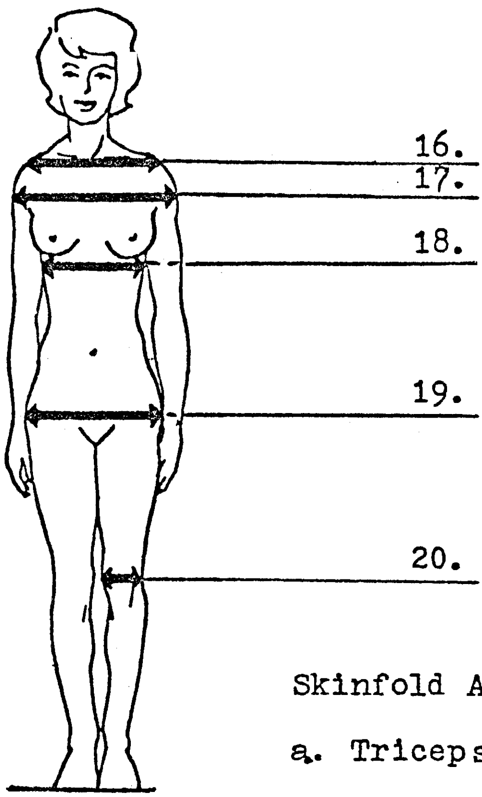


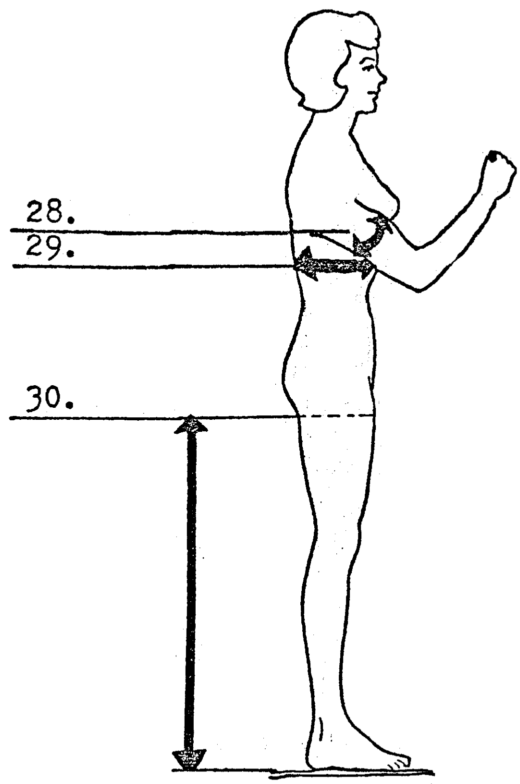




HAND SPAN_________________ 14.

HAND LENGTH_______________ 15.



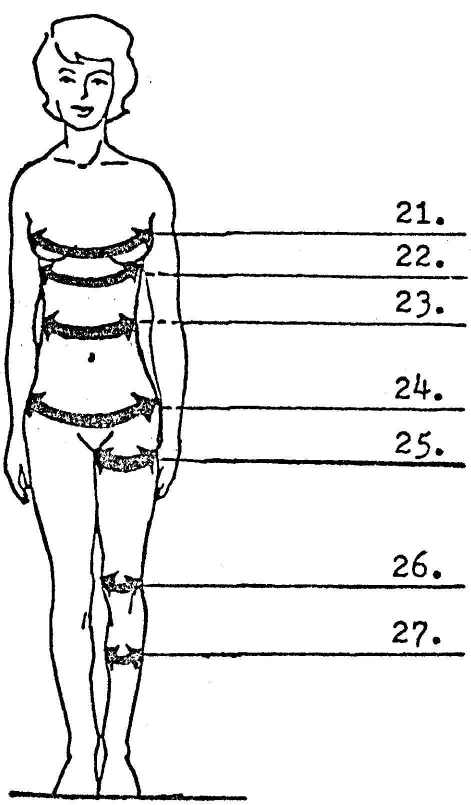


Skinfold Assessments:

a. Triceps ______________ 31.

b. Scapula ______________ 32.

c. Umbilicus ______________ 33.



Legend

1. weight
2. stature
3. arm span
4. maximal reach
5. functional reach
6. sitting height
7. eye height, sitting
8. shoulder height, sitting
9. waist height, sitting
10. hip breadth, sitting
11. buttock-knee length
12. knee height, sitting
13. buttock-leg length
14. hand span
15. hand length
16. biacromial breadth
17. bideltoid breadth
18. chest breadth
19. hip breadth
20. knee breadth
21. bust circumference
22. chest circumference
23. waist circumference
24. hip circumference
25. upper-thigh circumference
26. knee circumference
27. calf circumference
28. chest depth
29. biceps
30. crotch height

Skinfold Assessments:

31. triceps
32. scapula
33. umbilicus

APPENDIX B

DEFINITION OF TERMS AND MEASUREMENTS ASSESSED IN THE STUDY

1. Frankfort Plane: The positioning of the head wherein the lower border of the orbit, (bony socket of the eye) and the top of the ear lobe are in the same horizontal plane.[1]

2. Stands Erect: Subject stands on a flat surface, her weight distributed equally on both feet, with her back held in, her shoulders held back and her legs fully straightened. This position requires holding the body straight, but not rigid.[2]

The following measurements, terms, and techniques are suggested by Hrdlička[3] except those indicated with an asterisk which have been established by the investigator.

1. Weight: With subject standing erect, her weight distributed equally on both feet, all weights were taken on a balance-type scale. The subject was wearing outer clothing but was not wearing shoes. The weight was corrected by subtracting one half pound for clothing and then transferred to kilograms from a table of weights.

The following measurements were taken with the shoulder breadth caliper.

2. Biacromial breadth: With subject standing or sitting as tall as possible, her hands hanging naturally at her sides, the distance between the right and left acromial landmarks were measured. This measurement was best taken from behind the subject.

---

[1]Dupertuis, *Op. Cit.*

[2]*Ibid.*

[3]Aleš Hrdlička, *Anthropometry* (Philadelphia: Wistar Institute of Anatomy and Biology, 1920), pp. 10-33.

3. Bideltoid breadth: subject standing or sitting erect with her arms straight and her hands held closely against her thighs, the distance between the two deltoids at the maximal width was assessed by the investigator from behind the subject.

*4. Buttock-knee length: With subject sitting erect with her legs flexed in a right angle position and her feet resting on the floor, the investigator measured from the posterior aspect of the buttocks to the patella.

*5. Knee height, sitting: With subject sitting erect with her legs flexed in a right angle position, the investigator measured from the superior aspect of the knee to the floor. An adjustment was made by adding 1.6 centimeters to the length to allow for the thickness of the proximal arm of the caliper.

6. Chest breadth: With subject standing erect with her arms initially raised and then lowered when the instrument was in place, the researcher held the instrument on the surface at the level of the fifth rib. This measurement was taken from in front of the subject and was made during normal breathing. The average of the readings made during inspiration and expiration was recorded.

7. Hip breadth: With subject standing erect with her feet together from heel to toe, the transverse horizontal distance between the two greater trocanters (maximal breadth of the gluteus muscle while standing) was measured. This measurement was taken from behind the subject.

*8. Hip breadth, sitting: With subject sitting erect, looking forward, her knees resting on a surface so that the knees were bent at right angles, the posterior transverse distance between the two greater trocanters was measured. This measurement was taken from behind the subject.

9. Knee breadth: With subject standing with her dominant foot placed on a chair so that the leg was bent at the knee with the lower leg at right angles to the thigh, the investigator measured the maximal distance between the medial and lateral epicondyles of the femur.

The following measurement was taken with the chest depth caliper.

10. Chest depth: With subject standing erect, her arms hanging naturally at her sides, the researcher measured the distance between the anterioposterior of the rib from the sternum to the vertebral column in the back at about the level of the spinous process of the ninth thoracic vertebra. The measurement was taken during normal breathing. The average of the readings were made during inspiration and expiration.

The following measurements were taken with an anthropometric tape.

*11. Bust circumference: With subject standing erect, her arms initially raised and then lowered when the tape was in place, this measurement was taken at the nipple level (maximal girth of the breasts). This measurement was best taken from in front of the subject who was not wearing a brassiere.

12. Chest circumference: With subject standing erect, her arms initially raised and then lowered when the instrument was in place, this measurement was taken as high under the breasts as possible in the two stages of respiration and an average of the readings was recorded. The investigator stood in front of the subject while taking the measurement.

13. Waist circumference: With subject standing erect with her arms initially raised and then lowered when the tape was in place, the researcher stood in front of the subject while measuring the narrowest circumference between the lower ribs and the iliac crest, the plane of the tape being at right angles to the spine. A mark was inscribed at the place of the tape in order to obtain an accurate landmark for the sitting waist height measurement.

14. Hip circumference: With subject standing erect, her arms initially raised and then lowered when the tape was in place, this measurement was taken at the maximal girth of the gluteus maximus, the plane of the tape being at right angles to the spine and parallel to the floor.

*15. Waist height, sitting: With subject sitting erect, the distance was measured from the mark inscribed at the level of the minimal waist circumference to the seating surface.

16. Hand length: Subject's hand was measured from the dactylion (most distal point on the midfinger, not counting the nail) to the midpoint on the bistyloid line which connects the styloid process of the radius and the styloid process of the ulna, the most distal line on the wrist connecting the two styloids.

*17. Hand span: Subject's dominant hand was placed in a maximal span position on a flat surface superimposed upon a measuring tape. The distance between the most distal tip of the thumb and the most distal point of the phalangial is measured.

*18. Arm span: With subject standing erect with her arms extended in the frontal plane, shoulder high and parallel to the floor, the distance between the right and left dactylion was measured. This measurement was best taken with a tape measure attached to the wall. Subject stood facing the wall with her arms extended. See appendix page 110.

All limb measurements were taken on the dominant side.

19. Upper-thigh circumference: With subject standing with her feet about one foot apart with the weight evenly distributed on both legs, the tape was passed around the thigh at right angles to its long axis, and the maximal girth of the thigh was measured, just below the gluteal furrow.

20. Calf circumference: With subject standing with weight evenly distributed on both feet, the girth of the calf was measured at the largest part of the calf.

*21. Knee circumference: With subject standing erect, the researcher measured the maximal girth around the medial and lateral condyles of the dominant femur.

22. Biceps: The subject's dominant arm was held downward, straight and very slightly separated from the body. The tape was passed around the arm approximately half-way between the acromion and radiale at the largest part of the arm. The subject was requested to flex the elbow and contract the biceps muscle. The investigator measured the largest girth over the biceps at maximal contraction.

23. Crotch height: Subject stood erect with her feet approximately one foot apart. While standing in front of the subject the investigator measured from the inferior symphysis pubius, adjacent to the gracilis muscle, to the standing surface.

The following measurements were taken with a stadiometer.

24. Stature: Subject stood erect and as tall as possible the head being held in the Frankfort Plane. With the anthropometer arm touching the scalp, the vertical distance from the standing surface to the top of the head was measured. This measurement was best taken from the side taking great care that the anthropometer is in the vertical position. The height was recorded in inches and transferred to centimeters.

*25. Sitting height: Subject sat erect, the head oriented in the Frankfort Plane, and her feet resting on a surface so that her knees were flexed at right angles. With the anthropometer arm firmly touching the scalp the investigator measured vertically from the sitting surface to the top of the head. This measurement was taken in inches and later converted to centimeters.

26. Shoulder height, sitting Subject sat erect looking forward and her feet resting on a surface so that her knees were bent at right angles. With the anthropometer arm firmly touching the superior aspect of the acromin process, the researcher measured vertically from the sitting surface to the top of the acromion process. This measurement was taken in inches and converted later to centimeters.

The following measurements were taken with a special length caliper with a sliding arm which was developed within this laboratory, using a meter stick that had a dowel rod which the subject could grasp and extend for arm measurements. See appendix page 111.

*27. Eye height, sitting: Subject sat erect, looking forward her feet resting on a surface so that the knees were bent at right angles. Using the meter stick and sliding dowel, the investigator measured the vertical distance between the sitting surface and the inner corner of the eye.

*28. Functional reach: Subject sat or stood erect with her shoulders flat against the wall, her dominant arm extended in the saggital plane, shoulder high, her arm parallel to the floor and her fingers flexed while grasping a dowel. The investigator measured the distance between the wall and the dowel in the hand.

*29. Maximal reach: Subject sat or stood erect with her shoulders flat against the wall, dominant arm extended in the saggital plane, shoulder high, fingers extended and hand midway between pronation and supination. The researcher measured the distance between the wall and the most distal point of the dactylion.

*30. Buttock-leg length: Subject sat erect with her dominant leg fully extended and her foot in dorsi flexion. The investigator measured the distance from the posterior of the buttocks to the plantar surface of the *os calcaneum*. Eighteen centimeters were added to this measurement because the meter stick affixed to the stadiometer was not long enough to measure the leg plus the pelvic depth. See appendix, page 110 for illustration.

The following sites for the skinfold measurements were recommended:[1]

*31. Triceps: Subject stood erect. The caliper was applied to the skin midway between the acromion and olecranon processes over the middle of the tricep muscle with the arm straight and downward and the blades of the caliper parallel to the long axis of the arm.

*32. Scapula: Subject stood erect. The measurement was made by the researcher at the fold diagonally from the vertebral column toward the inferior angle and slightly toward the midline of the body.

*33. Umbilicus: Subject stood erect. The measurement was taken by the researcher five centimeters to the right of the umbilicus, the skinfold oriented laterally

---

[1]Letter from Josef Brožek, Department of Psychology, Lehigh University, Bethlehem, Pennsylvania, November 8, 1967.

[2]Narragansett, *Op. Cit.*

and the Caliper being approximately one centimeter away from the thumb toward the umbilicus.

The following items of equipment from the Narragansett Gymnasium Equipment Company were utilized in this study.

1. Anthropometric Tape: (Gulick Type Number 587) An anthropometric tape, reinforced with metal, with a six ounce spring attachment, which is graduated into inches on one side and centimeters on the other side, was used.

2. Shoulder breadth caliper: (Number 953) A wooden caliper was utilized which has a reinforced metal frame and is graduated into inches and tenths on one side and centimeters on the opposite side.

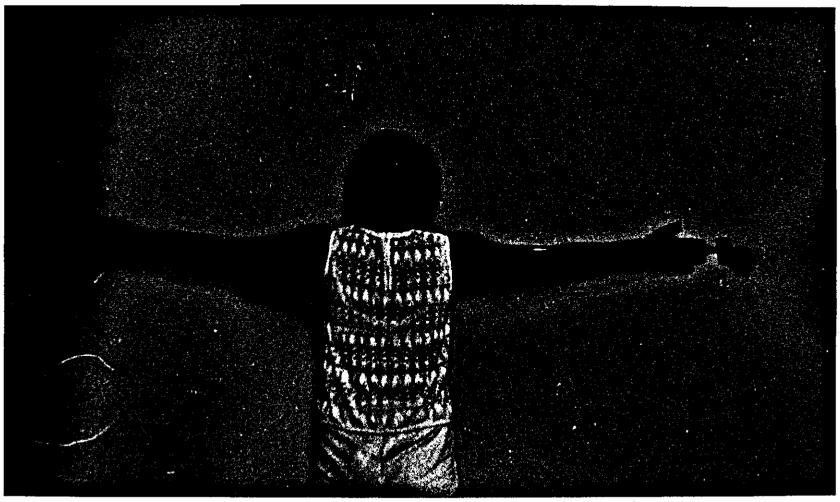
3. Scale: (Number 590-D) A gymnasium balance beam scale "Medic" type was used throughout the study. This scale is accurate to $\pm$ .25 of a pound.

4. Stadiometer or height stand: (Number 591) The base of the stadiometer is an eighteen inch square bench twelve inches high. An upright rod graduated into inches and tenths was inserted into the base of the stand. The sliding arm was designed so that measurements may be made from its upper as well as lower surface.

5. Chest depth caliper: (Number 585) The caliper is designed with constant spring pressure and is capable of taking maximal and minimal chest depths at the same time.

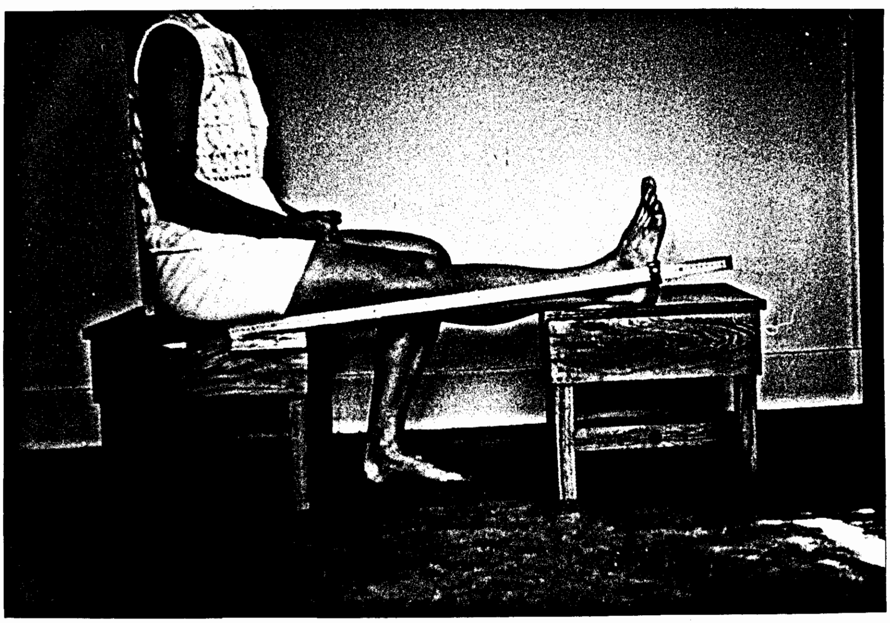
APPENDIX C

PLATE X



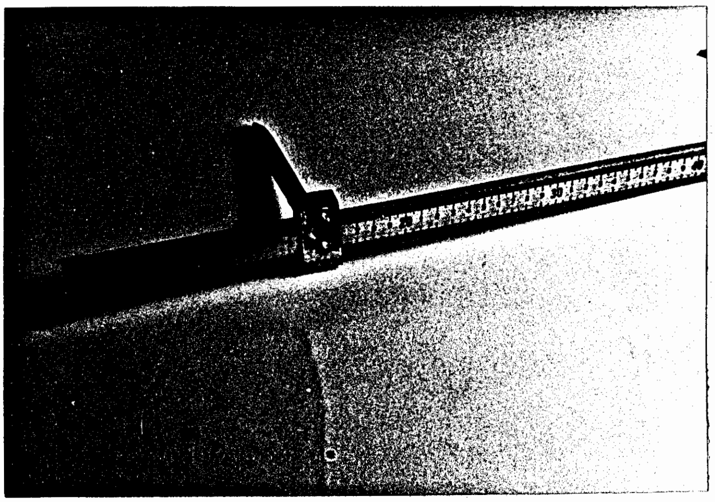
METHOD FOR ASSESSING THE ARM SPAN MEASUREMENT

PLATE XI



METHOD FOR MEASURING THE BUTTOCK-LEG LENGTH

PLATE XII



INSTRUMENT DEVISED IN THE LABORATORY
FOR MEASUREMENT OF THE MAXIMAL AND FUNCTIONAL
ARM REACH, EYE HEIGHT, SITTING, AND BUTTOCK-
LEG LENGTH

APPENDIX D

FORMULAS USED IN THE STATISTICAL ANALYSIS OF THE DATA

Correlation Coefficients[1]

$$r_{jk} = \frac{S_{jk}}{\sqrt{S_{jj}}\ \sqrt{S_{kk}}}$$

Where $j = 1,2 \ldots, m$; $k = 1,2 \ldots, m$.

Standard Deviations[2]

$$s_j = \frac{\sqrt{S_{jj}}}{\sqrt{m-1}}$$

Where $j = 1,2 \ldots, m$.

Means[3]

$$\bar{X}_j = \frac{\sum_{i=1}^{n} X_{ij}}{n}$$

Where $j = 1,2 \ldots, m$.

---

[1] IBM, Programmer's Manual, System/360 Scientific Subroutine Package (360A-CM-)3X) Version II, Vol. H20-0205-2. 3rd Ed. (IBM, 1967), p. 23.

[2] Ibid.

[3] Ibid.

Standard Error[1]

$$SE_m = \frac{S}{\sqrt{N}}$$

Reliabilities[2]

$$r = \frac{N(\Sigma XY) - (\Sigma X)(\Sigma Y)}{\sqrt{\left[N\Sigma X^2 - (\Sigma X)^2\right]\left[N\Sigma Y^2 - (\Sigma Y)^2\right]}}$$

t Test for Reliability[3]

$$t = \frac{r\sqrt{N-2}}{\sqrt{1 - r^2}}$$

---

[1] Garrett, *Op. Cit.*, p. 119.

[2] Quinn, McNemar, *Psychological Statistics*, 3rd ed. (New York: John Wiley and Sons Inc., 1962), p. 112.

[3] *Ibid.*, p. 138.