YEARBOOK OF PHYSICAL ANTHROPOLOGY 1978,
Yearbook Series Volume 21

Anthropometry and Human Engineering

ROBERT M. WHITE
U.S. Army Natick Research and Development Command, Natick, Massachusetts

KEY WORDS anthropometry · human engineering.

Anthropometry has a long tradition as a recognized part of physical anthropology. Although there is a general lack of interest in anthropometry among many physical anthropologists today, anthropometric data have become widely utilized and applied in the field of human engineering, which is concerned with the integration and compatibility between man and all kinds of equipment. The need for anthropometric data for use in human engineering is constantly increasing and potential opportunities for the applications of anthropometry are expanding rapidly. The sources of anthropometric data on the U.S. military population and on the U.S. civilian population of adults and children are reviewed. Sources of anthropometric data from various foreign countries also are reviewed briefly. The literature on anthropometry and human engineering is discussed and an extensive bibliography of 105 references is provided.

INTRODUCTION

Anthropometry—the measurement of the human body—has had a long history. Historically and traditionally the collection and analyses of anthropometric data have been recognized as integral parts of physical anthropology. The use of anthropometric data on skeletal remains or on the living for purposes of classification or for racial investigations filled an important role in the early years of the development of physical anthropology as a science and as a discipline.

During the past 50 years or so, the utilization of anthropometric data for practical applications gradually has grown and has received increasing attention. This specialized area of effort sometimes has been identified as applied physical anthropology or applied anthropometry. Recently it also has been called engineering anthropometry in a book on engineering anthropometry methods by Roebuck, Kroemer and Thomson ('75).

An encyclopedic review of measurement techniques in anthropometry, entitled *A Collation of Anthropometry* and consisting of 2,176 pages in two volumes, has been published by Garrett and Kennedy ('71). It is significant that the authors saw fit to include the following statement at the beginning of their monograph:

> One of our cited references states: "The great era of anthropometry has long ago come to an end. As a field of research it has occasionally been said to be obsolete and definitely passé." We dedicate these volumes to our colleagues who, by applying anthropometric data to the solution of innumerable design problems, have helped stay that verdict.

It is ironic that there is very little interest in anthropometry today among academic physical anthropologists. In spite of the fact that relatively few physical

anthropologists seem to be concerned with practical applications, the need for anthropometry and the potential opportunities for its applications have steadily increased. The result has been that others who are keenly aware of this need have come to support the anthropometry which physical anthropologists by training are best qualified to carry on but which they have defaulted through lack of concern or interest.

HUMAN ENGINEERING

The utilization and applications of anthropometric data have come to be recognized primarily in the field of human engineering. This interdisciplinary field, combining both research and application, is known in the United States as human engineering (or human factors engineering), but is known more widely in Europe and other parts of the world as ergonomics.

Human engineering has to do primarily with the integration, compatibility, performance, safety and comfort of human beings within man/equipment systems. While a great deal of work in this field was carried on even before the term human engineering came into use and recognition, human engineering has developed relatively recently.

While human engineering or human factors activities were carried on during and following World War II, a Human Factors Society was not established officially in the United States until 1956. The organization originally was called the Human Engineering Society, then the Human Factors Engineering Society of America, and finally the Human Factors Society. With a membership of over 1,850, this scientific and professional association includes primarily engineers, psychologists, industrial designers, and others, as well as even a few physical anthropologists. The Human Factors Society is pointed out here, since it is the organization whose members are the leading practitioners of human engineering in this country.

A fundamental concept in human engineering is the systems approach. According to this concept, the man together with his equipment, whether it be equipment he is using or a machine he is operating, is considered to be a man/equipment system. Further, a basic requirement for the efficient use and operation of such a system is that the man and the equipment be compatible. This, of course, is not a new idea, since hand tools and other such equipment have been designed and sized according to individual specifications for hundreds or even thousands of years. But with modern technology, industrial capability and mass production, the concept of man/equipment integration and compatibility has been moved up to higher levels of sophistication and complexity, at least in some countries.

Human engineering is considered to be the main focus of attempts to improve man's use of equipment and machines. Human engineers are concerned with the integration, compatibility and interface between man and equipment. However, whether at a simple level or at a highly complex level, the human being is still one of the two primary components in the man/equipment or man/machine equation. It follows, then, that information on the human being must be an important part of human engineering, at whatever level. Knowledge of man's body size and proportions, his capabilities and performance, his physiology and reactions all are needed. Body size information, in the form of anthropometric data, represents one of the basic and essential inputs in effective human engineering.

Most physical anthropologists are familiar with anthropometry, but many physi-

cal anthropologists are neither aware of nor concerned with the practical applications, actual or potential, of anthropometry. On the other hand, most human engineers recognize the importance of anthropometry in human engineering, but many human engineers are not familiar with the availability, sources, or current status of anthropometry. A review of the sources and current status of anthropometry in the United States, particularly with respect to applications in human engineering, is the primary purpose of this paper.

U.S. MILITARY ANTHROPOMETRY

Ever since World War I, the collection, analyses and applications of anthropometric data on U.S. military populations have been carried on as an integral part of military research and development programs. As a result, a great deal more body size information has been amassed for military personnel, both men and women, than for the civilian population of the United States.

Since effective human engineering requires the use of body size data on the specific population for which the equipment is intended, military anthropometry is one important source of the information necessary for the design and sizing of equipment and materiel to be used by the Armed Forces. Through the compilation, processing, analyses and synthesis of anthropometric data on large, representative samples of the military population, it is possible to provide a metric description of that population. This information then is available for general use in the design and human engineering of military equipment and materiel, as well as for specific application in the design, sizing and tariffing of military clothing and individual equipment.

Military anthropometry in the United States is not a new or even recent development, since anthropometric data on military personnel have been in use for at least 100 years or more. Information on the body size of Civil War soldiers was reported by Gould (1869) and by Baxter (1875). While these data include only a few body measurements, they do provide some indication of the body size of soldiers of some 100 years ago.

A large volume of anthropometric data and statistics on World War I soldiers was published by the Medical Department of the U.S. Army. In this monumental work, Davenport and Love ('21) analyzed data on some 2,000,000 draft recruits of 1917–1918, and on 100,000 troops demobilized in 1919. While a large part of the material in this volume consists of medical or clinical information, it is significant that extensive analyses were made of the correlations between body size and clothing size. In fact, many of the procedures utilized today in applied military anthropometry may be traced to the work of Davenport and Love in 1921.

Interest in the utilization and application of anthropometric data was renewed in the U.S. Army Air Forces early in World War II with the establishment of the Anthropology Branch at the Aero Medical Laboratory, Wright Field, Dayton, Ohio, where physical anthropologists conducted anthropometric surveys and carried out human engineering work on aircraft cockpits, gun turrets, oxygen masks and flight clothing throughout the War. A summary of this work in applied anthropometry was published by Randall et al. ('46).

Following his active duty in the Army Air Forces, Francis E. Randall transferred to the U.S. Army Quartermaster Corps, where he planned and directed the Army anthropometric survey of 1946. This was the first extensive survey to be conducted

primarily to provide body size data for military clothing and tariffing; it included the measurement of both men and women. In this survey, 105,062 Army men were measured at six separation centers; of the total series, 96,381 men were separatees, and 8,681 men were new inductees. Sixty-six body measurements were obtained on all individuals, while body build photographs were taken of 49,500 men. In the series of 8,864 Army women measured, 5,216 were Women's Army Corps (WAC) personnel, while 3,648 were Army nurses. The data from these Army surveys were published in a series of some 12 technical reports between 1947 and 1952 (White, '77). The basic data on women were reported by Randall and Munro ('49), and the data on men were reported by Newman and White ('51). Extensive research on the body build photographs of Army men was carried out by E. A. Hooton at Harvard University; his contract reports were published in 1959 (Hooton, '59).

Even prior to the U.S. Army Quartermaster Corps anthropometric survey of 1946, two important anthropometric studies were carried out in the Army. In the first study, 40 anthropometric measurements of the head and face were made on 3,075 Army men in 1945, as a basis for the development and sizing of gas masks. Following analyses of the data, a set of 10 bronze headforms was produced; these are still in use today—30 years later. In the second study, 27 measurements were made on the feet of over 7,500 Army men at Fort Knox, Kentucky. Analyses of these foot data have been used extensively for many years in the development and sizing of military footwear. Physical anthropologists participated in both of these studies, which are unique, as they have never been repeated in this country. Reports on the head and face study were published in 1945 (Brues, '45; Chemical Warfare Service, '45) and a report on the Fort Knox foot study was published in 1946 (Freedman et al., '46). The foot data also were later subjected to a factorial analysis by Jeffrey and Thurstone ('55).

As an outgrowth of the Army's work in anthropometry and clothing, a similar effort was initiated in the United States Marine Corps in 1948. This resulted in a survey of 2,000 Marine Corps men, carried out by William J. Beer, a Marine Corps officer. The anthropometric data collected were used extensively in the development and sizing of Marine Corps clothing and equipment, but unfortunately the data were never published in report form.

Another anthropometric survey was carried out by the U.S. Army Quartermaster Corps in 1949, primarily to obtain additional data on Army men in the younger age groups. In this survey, 7,272 men were measured, including 1,938 draftees, 3,921 enlistees, and 1,413 reenlistees. Although these data have been utilized in research, they have not been published.

With the establishment of the United States Air Force as a separate service, anthropometric surveys of Air Force personnel were carried out in 1950–1952. A series of 4,063 USAF flying personnel was measured at 14 air bases in 1950; 132 body measurements were taken. This series consisted of 61% officers, 15% cadets, and 24% enlisted men. In 1952, a survey of 3,332 Air Force male basic trainees was conducted, in which 60 measurements were taken. Also in 1952, 63 measurements were taken on a series of 852 Women's Air Force (WAF) female basic trainees. The anthropometric data from these three surveys have been published in a large number of technical reports (Reid, '76). The basic report on USAF flying personnel by Hertzberg, Daniels and Churchill ('54) has been widely

used as a standard reference for anthropometric data. The series of USAF male trainees was reported by Daniels, Meyers and Churchill ('53), while the WAF data on women were reported by Daniels, Meyers and Worrall ('53).

To meet an increasing need for specific data on personnel in Army aviation, an anthropometric survey of U.S. Army aviators was carried out in 1959. The data, consisting of 41 measurements on 500 Army pilots, were reported by White ('61).

Anthropometric data on 1,190 U.S. Navy pilots were collected in 1957–1958, based upon 25 measurements. Subsequently, a more extensive survey of 1,549 Navy and Marine Corps aviators was carried out in 1964, in which 96 measurements were taken. The earlier work was reported by Gifford ('60), while a report on the 1964 survey was published by Gifford, Provost and Lazo ('65).

New anthropometric surveys of the U.S. Armed Forces were proposed in 1964 by the Defense Supply Agency, with the ultimate objective of achieving improvements in the sizing, fit, tariffing, distribution and issue of military clothing and personal equipment. The purpose of the new surveys was two-fold. Initially, there existed a requirement for the updating of anthropometric data on the U.S. military population. Since the basic Army data were some 20 years old and the Air Force data were about 15 years old, new body size information was required for the younger generations of men in the Armed Forces. Secondly, it was recognized that data should be obtained for all of the Armed Forces, so that surveys were planned to include samples from the major groups comprising the U.S. military population.

In planning the anthropometric surveys, it was agreed that surveys of Army, Navy, and Marine Corps personnel would be conducted by U.S. Army anthropologists, while those of Air Force personnel would be carried out by Air Force anthropologists. Following a year of planning, preparation and coordination, the surveys were initiated in August, 1965, when the Air Force obtained 158 measurements on a series of 2,632 USAF basic trainees. Seventy body measurements were taken in the Army, Navy, and Marine Corps surveys, which were carried out between November, 1965, and April, 1966. The total Army series of 6,682 men included 2,639 basic trainees, 3,429 infantry personnel, 489 armored crewmen, and 125 Army aviation personnel. The Navy series consisted of 4,095 recruits in training, while the Marine Corps sample comprised 2,008 men. The field work of these surveys was completed in 1967, when the Air Force obtained 187 measurements on a series of 2,420 USAF flying personnel between January and March, 1967. The data on the 1967 flying personnel were included in a NATO-AGARD report edited by Grunhofer and Kroh ('75), and subsequently, the Air Force data from both 1965 and 1967 were published in a report by Churchill, Kikta and Churchill ('77). The U.S. Army data were published by White and Churchill ('71), while the Marine Corps data were also reported by White and Churchill ('77); the data on Navy recruits have not been published as yet.

The anthropometric surveys of the U.S. Armed Forces, carried out between 1965 and 1967, represented a new approach in that for the first time standard body measurements were taken in coordinated surveys on personnel of all the military services within the same time frame. These data provided a basis for describing the body size of the U.S. military population at that time and made possible direct comparisons of body size among Armed Forces personnel.

Following the Armed Forces surveys, two anthropometric surveys of U.S.

Army aviation personnel were carried out. In the first, nine body measurements were made on a series of 1,640 Army warrant officer candidate flight trainees in 1968 and reported by Schane, Littell and Moultrie ('69). In the second, a series of 1,482 Army aviators was measured in 1970; 85 measurements were taken, and the data were reported by Churchill et al. ('71).

An anthropometric survey of U.S. Air Force women was conducted in 1968, in which 137 measurements were made on a sample of 1,905 women, including officers, Air Force nurses, and enlisted women. This survey was reported by Clauser et al. ('72). In the most recent U.S. military anthropometric survey, carried out in 1976–1977, 128 body measurements were made on a sample of 1,331 U.S. Army women, including officers, Army nurses, and enlisted women. In addition to the anthropometry, data also were collected on smaller series of women for workspace measurements and for static muscle strength measurements. At the conclusion of the women's survey, a small sample of 287 U.S. Army men also was measured in order to obtain directly comparable anthropometric, workspace, and strength data for both Army men and women. The results of this survey have been published in a series of four technical reports by various authors: Laubach et al. ('77), E. Churchill et al. ('77), T. Churchill et al. ('77), and McConville et al. ('77).

In this summation of military anthropometry in the United States, it may be seen that Army men, Army women, Army aviators, Marine Corps men, Navy aviators, Air Force flying personnel, Air Force male trainees, and Air Force women all have been measured twice in major anthropometric surveys at various times during the past 30 years.

U.S. CIVILIAN ANTHROPOMETRY

With approximately 20 major anthropometric surveys during the past 30 years, a large amount of anthropometric data has been accumulated on U.S. military personnel, both men and women. By contrast, the paucity of reliable and representative anthropometric data on the U.S. civilian population is a serious shortcoming.

While it can be argued that military personnel are, of course, drawn from the civilian population and that military anthropometric data therefore are applicable where body size information is needed, there are some distinct constraints. The first and most obvious is that the military population is, by and large, a young population with a heavy concentration of individuals between 20 and 35 years of age, whereas the civilian population varies from the teens to the elderly, with a much greater range of age. Secondly, there is the constraint of selection in that the limits for stature and weight imposed in the physical standards used by the Armed Forces eliminate extremes of body size from military service. In general, anthropometric data for civilians show greater ranges of variation in body size and also higher standard deviations for body measurements than do military data. Despite these constraints, however, the lack of adequate civilian data for some body measurements forces the use of military data—there is no alternative. For instance, there are virtually no anthropometric data available on the heads and faces, the hands and the feet of U.S. civilian men and women.

The first major anthropometric survey of U.S. civilian women was carried out in 1939–1940 by the Bureau of Home Economics, U.S. Department of Agriculture,

with the assistance of the Works Progress Administration (WPA). In this project, 59 body measurements were taken on almost 15,000 women, primarily for application in pattern and garment construction. The report of the survey, including analyses of the data, was authored by O'Brien and Shelton ('41).

A limited number of body measurements were taken during a national Health Examination Survey of U.S. civilian men and women, carried out between 1959 and 1962 by the Public Health Service, U.S. Department of Health, Education, and Welfare (HEW). In this survey, covering individuals between 18 and 79 years of age, 3,091 men and 3,581 women were measured. Anthropometric data were obtained for 18 body measurements, including weight, stature, eight sitting measurements, three body breadths, three circumferences, and two skinfold thicknesses. The data were published in two reports by Stoudt et al. ('65; '70). Means and selected percentile values were given for men and women in the total series and in seven age groupings, but the exclusion of standard deviations or any ranges of variation was a glaring omission. While the sitting measurements taken in this survey are useful for human engineering applications, the data are of virtually no use for clothing design and sizing, and the lack of any data on the head and face, the hands and the feet was a serious shortcoming.

Preliminary data on height and weight have been reported by the U.S. Department of Health, Education, and Welfare as the result of a new health and nutrition examination survey in the United States, carried out between 1971 and 1974. It was reported (Abraham et al., '76; '77) that a total series of 20,749 persons between the ages of 1 and 74 years of age were examined; the preliminary data are based on 13,671 individuals aged 18–74 years. An article in *Time* magazine (January 2, 1978) reported increases in both height and weight for men and women in the U.S. population, based upon comparisons between the HEW data of 1960–1962 and 1971–1974. Further reports on these new data presumably are in preparation; however, anthropometric data other than age, height, and weight have not been mentioned in these preliminary reports.

The Department of Agriculture survey of women in 1939–1940 and the HEW surveys of men and women, with limited anthropometric data, are the only such surveys of civilians in the United States. As a consequence, there has been considerable discussion of the need for a new and definitive national anthropometric survey of U.S. adults. A meeting was held at the Department of Commerce in Washington in October 1973, to discuss such a survey, and proposals were presented by H. T. E. Hertzberg, A. F. Roche and R. E. Herron. While attendees at the meeting from both industry and government voiced general approval, financial support has not been forthcoming from either government or industry, and such a survey has never been initiated. However, a preliminary study report on the development of a national anthropometric data base was issued by the National Bureau of Standards (Steinberg, '74). Preliminary estimates on the order of five to six million dollars for a five to six year effort have been made for a comprehensive national anthropometric survey, together with processing, analyses and publication of the data. H. P. Van Cott and his staff of the Center for Consumer Product Technology at NBS are engaged in a continuing feasibility study to define the requirements and objectives for such an effort, which would include not only anthropometric data, but other data on human performance as well.

Some anthropometric data on U.S. civilians may be found in a number of limited surveys or studies which have been carried out over the years. While

data of this type may be useful for some specific applications it must be pointed out that the individuals measured in such studies comprise selected or specialized samples which are not necessarily representative of the total civilian population.

Ernest A. Hooton at Harvard not only was an admirable teacher, but he also served as a consultant to the Army and the Air Force in the early years of applied anthropology. His 1945 survey of seating for the Heywood-Wakefield Company often is cited as a classical study in human engineering. Carleton S. Coon, Wilton M. Krogman and T. Dale Stewart each in their own way have long recognized the fundamental importance of anthropometry and its utilization and applications.

An early pioneer in human engineering was the late Ross A. McFarland, whose group of researchers at the Harvard School of Public Health carried out investigations in the automotive field, as well as in aviation and aerospace medicine. Human body size and capabilities in the design and operation of vehicular equipment was discussed in one of their early studies in human engineering (McFarland et al., '53), which included anthropometric data on civilian as well as Army drivers. In a later study, static and dynamic measurements of drivers were presented, based upon 11 measurements of 509 men and 524 women (Stoudt et al., '70).

For some years, anthropology has been a part of the research program carried on at the Federal Aviation Administration's Civil Aeromedical Institute in Oklahoma City. Physical anthropologists conducted an anthropometric survey of air traffic control trainees in 1961, in which 64 measurements were obtained on a series of 680 men (Snow and Snyder, '65). In an anthropometric survey of airline stewardess trainees in 1971, 72 measurements were taken on 422 women (Snow, Reynolds and Allgood, '75), while the functional strength capabilities of 152 stewardesses were measured in another study (Reynolds and Allgood, '75).

With the gradual increase in the proportion of older people in the U.S. population, the availability of anthropometric data on older age groups is becoming more important. The HEW series of men and women do include some data on individuals up to 79 years of age. An anthropometric study of a series of 130 Spanish-American War veterans was carried out in 1959 (Damon and Stoudt, '63). The subjects ranged between 72 and 91 years of age, with a mean age of 81.6 years; 47 measurements were taken. Damon and Stoudt also participated in the initiation of a normative aging study of U.S. male veterans, being conducted by the Boston Outpatient Clinic of the Veterans Administration (VA). In the first round of the study, 51 measurements were made on a series of 2,200 men who had an average age of 43 years, with a range in age between 22 and 82 years. Anthropometric data have been reported for the total series and for six age groupings (Damon et al., '72). This VA study is continuing and a second round of measurements has been made, but the results have not been published as yet.

The most recent anthropometric survey of U.S. civilian men was carried out in 1974, when personnel of the Naval Electronics Laboratory Center in San Diego measured a national sampling of 3,000 law enforcement officers; 23 body measurements were taken (Martin et al., '75). The survey was performed under contract for the Law Enforcement Standards Laboratory of the National Bureau of Standards. The anthropometric data from this survey have been utilized extensively in the development and sizing of protective clothing and equipment for police, agents and other law enforcement officers.

A review of anthropometry and human engineering in the United States would be incomplete without mention of the late Henry Dreyfuss, who was known

primarily for his successful efforts to popularize the use of body size information through his publications on industrial design (*Designing for People*, '55; *The Measure of Man*, '67). Henry Dreyfuss Associates more recently have produced *Humanscale 1/2/3* (Diffrient et al., '74). This is a kit consisting of three plastic cards with rotary selector dials, by means of which anthropometric data are presented in series of windows. The material purports to show body measurements of men and women, link measurements, a seating and seat/table guide, as well as data on wheelchair users, on the handicapped (users of crutches, canes) and on the elderly. A booklet is provided with the kit which discusses use of the data and includes selected literature references. This rather slick (and copyrighted) anthropometric gadget has not been well-received by anthropologists and human engineers. Critical reviews of it have pointed out that with the greatly oversimplified presentation of anthropometric data, no adequate explanation has been given for the derivation and analyses of the data, so that designers or others looking for body size information can only accept at face value the numbers shown in the little windows. Naive users of this material are on their own.

One last word of warning—do not always accept everything seen in print. In 1957, Cleveland Designers and Consultants, Inc., produced a copyrighted pamphlet (price $1.00) entitled *Dimensions of the Human Figure* (Sahley, '57). Data for 99 body measurements of men and women are presented and illustrated, including "normal deviations" (sic) and an impressive bibliography. The introduction in this publication states: "The dimensions given are those of Americans, 6,283 of them, selected at random in Cleveland, Ohio. Cleveland is a noted melting pot and comprises about 1% of the national population. A random selection includes every nationality and race commonly met, covering all adult groups and all walks of life." This publication is a fraud, pure and simple, as the data for both men and women were "lifted" from U.S. Air Force technical reports (Hertzberg et al., '54; Daniels et al., '53) and in no way represent the population of Cleveland or any other civilian population.

ANTHROPOMETRY OF U.S. CHILDREN

While, of course, there have been many longitudinal and growth studies of U.S. children in which some body measurements have been taken, the first major anthropometric survey of children was carried out between 1937 and 1939 by the Bureau of Home Economics, U.S. Department of Agriculture, with the assistance of the Works Progress Administration. A sampling of 147,088 boys and girls from 16 states was made, with ages ranging from 4 to 17 years; 36 body measurements were taken. The report on this work was published by O'Brien, Girshick and Hunt ('41).

As a part of the National Health Survey, a Health Examination Survey has been carried on by the Public Health Service, U.S. Department of Health, Education, and Welfare. The Health Examination Survey was conducted in three "cycles." The first "cycle" was the examination of adult men and women between 1959 and 1962. The second "cycle," carried out between 1963 and 1965, included the examination of 7,119 children between 6 and 11 years of age, while the third "cycle," between 1966 and 1970, consisted of the examination of youths between 12 and 17 years of age. A tremendous amount of information and data was accumulated during these surveys. Along with the clinical, medical, nutritional, social,

psychological and behavioral data, anthropometric data also were included, consisting of height, weight, five skinfolds and about 30 other body measurements. The anthropometry of 6-to-11-year-old children was presented in two reports by Malina, Hamill and Lemeshow ('73; '74). Height, weight, and skinfold thicknesses of the 12-to-17-year-old youths were presented in three reports by Hamill, Johnston and Lemeshow ('73a,b) and Johnston, Hamill and Lemeshow ('74).

Another useful source of current anthropometric data on U.S. children may be found in the publications of R. G. Snyder and his colleagues at the University of Michigan. This group initially prepared a compilation of source data of infant and child measurements for the Children's Hazard Division, Bureau of Product Safety, Food and Drug Administration (Snyder et al., '72). The continuing and increasing concern involving the human engineering aspects of design and safety for the protection of children has emphasized the need for anthropometric data on children for many applications (furniture, toys, etc.). This need was recognized by the Consumer Product Safety Commission, and an anthropometric survey of children was carried out by Snyder and his co-workers under contract. A total of 41 body measurements were taken between 1972 and 1975 on 4,027 infants and children, representing the U.S. population from 2 weeks to 13 years of age. Automated measuring instruments and equipment were used. A report by Snyder et al. ('75) presented the data from this survey. The work was continued in an extension of the children's survey between 1975 and 1977, in which 87 traditional and functional measurements were taken on 4,127 infants, children and youths between 2 weeks and 18 years of age. The report of this survey also was published by Snyder et al. ('77).

It should be pointed out that an additional report from the University of Michigan group also includes further anthropometric data on children (Owings et al., '75). This report presents a comprehensive preliminary study of the muscular strength of a series of 502 children between the ages of 2 and 10 years. The results include data on 33 isometric exertion measurements: torques developed around the wrist, elbow, shoulder, ankle, knee, hip and trunk, together with the force of hand grip and several types of pinch. Of particular interest are the anthropometric measurements of linkage lengths (distances between the joint centers of rotation) for the same subjects.

As a result of the recent work by Snyder and his colleagues, the anthropometric data for U.S. children now are both quantitatively and qualitatively superior to the data available on the U.S. adult population.

ANTHROPOMETRY IN OTHER COUNTRIES

The discussion of anthropometry and human engineering so far has been limited to the United States. Interest in ergonomics and research in this field has been growing and expanding in Europe and in other parts of the world as well. In some aspects of ergonomics, some European countries actually are ahead of the United States in accomplishments; ergonomics also is an active field in Japan as well. The utilization of military anthropometry in particular has been emphasized in quite a few countries in recent years. A study project in anthropometry and its methodology has been initiated within the community of the North Atlantic Treaty Organization (NATO) countries.

Illustrative of the increasing world-wide interest in ergonomics or human factors

engineering was an interesting and significant symposium on national and cultural variables in human factors engineering, held in Oosterbeek, The Netherlands, in June, 1972, under the auspices of the Advisory Group on Human Factors of NATO. Forty-four participants representing 15 countries attended and participated. Anthropometry and variations in body size were discussed in several papers presented at this symposium. The papers have been collated and published in book form under the editorship of Chapanis ('75).

A brief review of recent foreign sources of anthropometric data begins with Canada. Canadian Forces personnel were measured in an anthropometric survey carried out in 1974. Thirty-two measurements were taken on 565 men and reported by McCann et al. ('75).

A survey to collect anthropometric data on military personnel of 18 Central and South American countries was conducted between 1965 and 1970 by the U.S. Army Tropic Test Center in the Canal Zone. Seventy-one anthropometric and four strength measurements were taken on a series of 1,985 men. While the sampling in this survey was by no means random, the anthropometric data are unique for military personnel of this area. The final report on this project was prepared by Dobbins and Kindick ('72).

Pioneering work in anthropometry and human engineering was carried on for many years in England by G. M. Morant. This work has been continued particularly at Farnborough, both at the Royal Aircraft Establishment (RAE) and at the Army Personnel Research Establishment (APRE). A continuing anthropometric survey is being conducted in the British Army by APRE. To date, 62 anthropometric measurements (and skinfold thicknesses) have been taken on 500 Royal Armoured Corps servicemen, 534 infantrymen, and 100 Guardsmen (Ince, Redrup and Piper, '73; Gooderson and Beebee, '76; '77). An anthropometric survey of 2,000 Royal Air Force aircrew was carried out by RAE in 1970–1971, consisting of 63 measurements (Bolton et al., '73), while 45 head and face measurements were taken on 500 Royal Air Force aircrew in 1972 (Hobbs, '73).

Two impressive anthropometric studies in applied anthropometry have been published by the Laboratory of Anthropology at the University of Paris, France. In the first, Coblentz and Ignazi ('67) reported 55 measurements of the hands of 150 French men. In the second, 67 head and face measurements were taken on a series of 2,000 French military personnel (Coblentz and Ignazi, '68).

In the Federal Republic of Germany, 153 anthropometric measurements and skinfold thicknesses, taken in 1967–1968, were reported for 1,465 German Air Force flying personnel by Grunhofer and Kroh ('75). H. W. Jürgens and his co-workers at the Anthropological Institute of the University of Kiel have published two reports on the anthropometry of German military personnel. In 1968–1969, 43 measurements were made on 7,144 20-year-old German draftees (Jürgens, Habicht-Benthin and Lengsfeld, '72), and in 1970–1971, 54 measurements were taken on 2,643 Armed Forces men between the ages of 25 and 40 years (Jürgens, Helbig and Lengsfeld, '73).

An anthropometric survey sponsored by the NATO Advisory Group for Aeronautical Research and Development (AGARD), was carried out in 1960–1961 in Turkey, Greece and Italy by H. T. E. Hertzberg and a team of U.S. physical anthropologists. A total of 150 measurements were taken on Armed Forces personnel: 915 in Turkey, 1,084 in Greece, and 1,357 in Italy. A comprehensive report of this survey by Hertzberg et al. ('63) was published in book form.

Two papers on anthropometry are available from South Africa. In the first, Morrison et al. ('68) reported 72 measurements on a series of 485 Bantu mine laborers, while in the second, 57 anthropometric measurements and skinfold thicknesses on 1,445 men of the South African Armed Forces were reported by Strydom et al. ('68). Twenty-eight foot measurements of 3,695 Australian Army men have been reported by Maclean ('68), as well as similar foot measurements on 1,000 Papua/New Guinea indigenous servicemen by McCallum and Henderson ('69). An anthropometric survey of the Australian Army was carried out in 1969 in which 11 measurements were made on 3,695 men (Australian Army, '70). In New Zealand, an anthropometric survey of RNZAF aircrew was conducted in 1972–1973, in which 62 measurements were taken on 238 men (Toulson, '74).

Moving on to Asia, anthropometric surveys of military personnel were carried out in Thailand in 1962 and in Vietnam in 1963. Fifty-one anthropometric measurements were made on 2,950 men of the Royal Thai Armed Forces (White, '64a) and on 2,128 men of the Armed Forces of the Republic of Vietnam (White, '64b).

In Japan, 62 anthropometric measurements were taken on 239 Japanese Air Self Defense Force (JASDF) pilots in 1961 (Oshima et al., '62), while 108 measurements were made on a total series of 1,176 JASDF personnel in 1972 (Japanese Air Self Defense Force, '72).

Republic of Korea Air Force (ROKAF) pilots were surveyed in 1961 when 132 measurements were taken on 264 men (Kay, '61). An anthropometric survey of 3,747 members of the South Korean Armed Forces was made in 1965, with 59 measurements taken (Hart, Rowland and Malina, '67). Several subsequent surveys of the Korean Army were made in 1968–1969 by Rowland and Company under contract, but the data have not been published.

A major anthropometric survey of the Imperial Iranian Armed Forces was carried out in 1968, with U.S. technical assistance. Sixty-eight measurements were taken on a total series of 9,414 men, including members of the Army, Navy and Air Force. A two-volume report by Noorani and Dillard was published in Teheran in 1970. As a follow-up to the anthropometric survey, a report discussing the applications of the data in the design and sizing of uniforms and combat boots was published in 1971 (Kennedy and White, '71).

Anthropometric surveys of military personnel also have been conducted in India and in Malaysia. An extensive monograph on the physical anthropology of Ceylon (now Sri Lanka) was published in 1961, based upon data collected by Marett (Stoudt, '61).

As an example of the need for anthropometric data on foreign populations, an interesting paper was published by the Society of Automotive Engineers in 1968, as a report from the SAE construction and industrial machinery technical committee. The paper, entitled "The Range of Anthropometric Measurements for Asian Populations," was prepared in order to present the extremes of body size in the entire Asian population, as representing potential operators of industrial and construction equipment such as tractors, loaders, bulldozers, etc. The anthropometric data consisted of data on Vietnamese military personnel from White ('64b) and data on Turkish military personnel from Hertzberg et al. ('63). While hardly representative of the tremendous scope of physical anthropology and anthropometry in Asian countries, these two countries at the eastern and western boundaries of Asia at least do show some of the extremes of body size to be found in the populations of this large part of the world.

The very superficial and cursory review of anthropometry in some foreign countries given above is, of course, by no means complete or exhaustive. Undoubtedly many other references, both older or more recent, could be mentioned. It does serve to point out, however, some of the more recent anthropometric surveys in various foreign countries and to suggest the proliferation of interest in anthropometry around the world.

TRENDS IN HUMAN ENGINEERING

In the foregoing review, the sources of anthropometric data in the United States and abroad have been summarized. It has been emphasized that body size information in the form of anthropometric data represents an important component of the human engineering process. An attempt will be made here to indicate some of the current trends in human engineering in the United States.

For about 25 years following World War II the main concentration of human engineering was to be found in the large companies engaged in the research and development of military systems—aircraft, vehicles, missile and weapons systems, and the like. This effort was continued through the years of the Korean and Vietnam conflicts, primarily supported through large government contracts. Large contracts enabled companies to expand their technical workforce, and they were even able to afford a staff of human engineering or human factors specialists. This was especially true in the large aerospace firms and in the electronics industry. Nevertheless, some of the early efforts in human engineering were largely of a token nature. To a large extent human engineering initially was barely tolerated as an interesting novelty; it was not regarded as of fundamental worth or importance.

As human engineering became more widely known and as the concepts and principles of human engineering became more firmly established, the situation began to change. This gradual change worked both ways. On the one hand, those responsible for negotiating and monitoring contracts on behalf of the Armed Forces began to include human engineering considerations in the contracts. In response, firms which could demonstrate expertise in human engineering found that they possessed a useful competitive advantage in bidding for contracts.

The practice of human engineering now is fairly well established in the Armed Forces of the United States. To a greater or lesser degree, both research and applied work are carried on in the Army, Air Force, Navy and Marine Corps. However, the Army and the Air Force are the only services to employ full-time professional physical anthropologists.

In commenting on the current status of human engineering, it is only fair to point out that the field suffers from an identity problem. The identity, if not the qualifications, of a chemist, a physicist, a lawyer, a physician, or even an engineer is fairly well established. Computer designers or computer programers have no trouble identifying themselves. Even anthropologists usually are able to somehow explain what they are. But when a specialist in human engineering is asked: "And just what do you do"?—what does he or she reply?

There is a wide diversity in human engineering today, and this in turn makes it difficult to establish a clear disciplinary definition of the field. The reasons for this appear to be two-fold. First, those who have come into human engineering, for whatever interest or inclination, have done so from a variety of backgrounds:

psychology, engineering, anthropology, industrial design, architecture or many other fields. Secondly, the educational and academic preparation for a human engineering specialist also may be varied and not clear-cut or well defined.

A cursory perusal of a pamphlet entitled Directory of Training Programs in Human Factors (3rd edition), published by the Human Factors Society (Kreifeldt and Ayoub, '76), indicates that 53 programs are offered in United States universities, including a variety of courses. As of 1976, it was reported that there were 1,322 students specializing in human factors, with 4,975 M.S.s and 380 Ph.D.s granted. In general, these programs are to be found mainly in departments of psychology or industrial engineering; they are largely at the graduate level.

Human engineering as practiced in the United States today may be characterized primarily by its wide diversification. To be sure, it is still used and emphasized in military research and development programs, but it is no longer limited to or concentrated in this area. The concepts, principles and ideas of human engineering have proliferated and spread into many fields, particularly in industrial and civilian, as opposed to military efforts. Industrial design, workspace planning and layout are obvious areas for human engineering, but human engineers now are interested and working in architecture and planning for schools, hospitals and other institutions, as well as airports and doctors' or dentists' offices, to name a few examples. Even household kitchens and bathrooms have received the attention of human engineers.

The design, function and use of a wide variety of consumer products occupies the attention of a large group of human engineering and human factors specialists. Safety, as well as consumer satisfaction, is an important element in this field. The area of product liability is one of increasing concern; human factors people now are being consulted not only for information and data related to product design, but are serving as expert witnesses in court cases. The Human Factors Society recently staged and filmed a successful and interesting mock trial of a liability case for informational and instructional purposes.

The transportation field in general and the automotive field in particular are areas in which a great deal of human engineering work is being done, not only in design and engineering, but also in driver behavior and related problems. One would suppose that the use of anthropometric data would be of basic importance in the automotive field. Anthropometry is utilized to some extent for automobiles, trucks, and busses, but concern for the human driver or passengers is still rather superficial; styling, engineering and marketing largely run the show in Detroit.

The whole area of clothing and apparel is one which involves human engineering only in the broadest sense, but the need for applied anthropometry here is rather obvious, to say the least. Managers and decision makers in the clothing industry will readily agree that anthropometric data are both useful and needed to improve sizing and fit in clothing, but where are the data? Progress in the improvement of clothing is hindered on two counts. First, there is a long and well-established tradition of fixed practices in the sizing, grading, and drafting of clothing patterns, further complicated by factors of design and styling. Secondly, there is a general naiveté or even ignorance among most clothing people concerning the statistics of anthropometric data. As in many other fields, problems in clothing will become even more acute as we move further into the metrication process and attempt to convert from inches to centimeters for clothing sizing and patterns. Needless to say, those physical anthropologists who are in the business of furnishing or

applying anthropometric data eagerly await the day when data collected in the metric system in the first place will no longer have to be converted into inches and fractions of inches!

Many other areas of human factors or human engineering interest could be cited or discussed. The widespread diversification and proliferation of human engineering is characteristic of its status today. The Human Factors Society not only has about 20 local chapters in all parts of the United States, but it also supports five active technical interest groups within its membership. These are groups specifically interested in computer systems, consumer products, environmental design, safety, and training.

LITERATURE

A final word on the literature. The results of military anthropometric surveys and the applications of anthropometric data usually are presented in technical reports or monographs published by the U.S. Armed Forces. Several annotated bibliographies are available. The U.S. Air Force has published an annotated bibliography of applied physical anthropology for some years; the latest edition by Reid ('76) includes summaries of Air Force publications between 1946 and 1976. An annotated bibliography of U.S. Army publications in physical anthropology has been published by White ('77). This includes summaries of technical reports, articles, and papers on anthropometry, applications, constitutional and environmental anthropology, and human identification published between 1947 and 1977.

An earlier annotated bibliography, published by the U.S. Department of Agriculture (O'Brien, '30), contains references to many of the older (1842–1929) publications and articles on anthropometry, anthropometric surveys, and the applications of anthropometric data in clothing design and sizing. Another annotated bibliography, of applied physical anthropology in human engineering, was published by the U.S. Air Force (Hansen, Cornog and Hertzberg, '58), containing summaries as well as data from the older literature. A third useful annotated bibliography in this area was published by the Defence Research Board in Canada (Staples, '64), containing a literature survey and critical review of the role of anthropometry in the sizing of clothing and personal equipment.

An indication that anthropometry and human engineering have achieved official recognition and status of sorts in the United States is the publication of Department of Defense documents which now include anthropometric data from military surveys. A military standard covering human engineering design criteria for military systems, equipment and facilities—MIL-STD-1472B (Department of Defense, '74) was first published in 1968, followed by revisions in 1970 and 1974; a new edition is in preparation. A military standardization handbook on human factors engineering design for Army materiel—MIL-HDBK-759 (Department of Defense, '75), containing Army anthropometric data, was first published in 1975; it is currently being updated. An engineering design handbook consisting of a metric conversion guide—DARCOM Pamphlet 706-470 (Department of the Army, '76), also contains Army anthropometric data.

There are also many bibliographies and handbooks in the field of human engineering which include anthropometric data. The most comprehensive is the human factors engineering bibliographic series covering the literature between 1940 and 1966. This was prepared at Tufts University and published in four volumes in

1966–1967 under the joint sponsorship of the Army, Navy and Air Force (Ronco et al., '66–'67). Unfortunately this valuable effort was discontinued several years ago.

A human engineering guide to equipment design, also sponsored by a joint Army-Navy-Air Force committee, was published in 1963 (Morgan et al., '63). This human engineering guide was subsequently revised in 1972 (Van Cott and Kinkade, '72), but the revision was some years in the preparation and the anthropometric data cited are now rather out of date. A bioastronautics data book was published by the National Aeronautics and Space Administration (NASA) in 1964 (Webb, '64), while a databook for human factors engineers, also sponsored by NASA, was published in 1969 (Kubokawa et al., '69).

The Human Body in Equipment Design, by Damon, Stoudt and McFarland ('66), represented a useful textbook in the field of applied anthropometry. While this volume contains an excellent presentation of the principles of human engineering, the anthropometric data cited also now are somewhat out of date. With reference to applied anthropometry, the authors stated in their preface: "Despite these efforts and the success of the few applied anthropologists currently active in military and industrial laboratories, the discipline remains an academic stepchild, untaught by university anthropologists and largely unavailable to their students as well as to students of psychology, engineering, architecture, and industrial design." The situation has not improved appreciably in the 12 years since that opinion was given.

In an excellent and more recent textbook entitled *Engineering Anthropometry Methods*, Roebuck, Kroemer and Thomson ('75) present a comprehensive and useful summary, including anthropometry and its applications in human engineering.

In summary, the sources of anthropometric data on the U.S. military population and on the U.S. civilian population of adults and children have been reviewed. Sources of anthropometric data from various foreign countries also have been reviewed briefly. Body size information in the form of anthropometric data is considered to be one of the basic requirements for effective human engineering. Although initially concentrated in military research and development programs, human engineering as practiced in the United States today has become widely diversified into many areas.

While academic physical anthropologists do not appear to be interested in or concerned with anthropometry or its applications in human engineering, a wide variety of opportunity exists today for young and imaginative physical anthropologists who might become interested in the potential usefulness of the applied field.

The following quotation, attributed to Albert Einstein, appeared recently in an issue of the Human Factors Society Bulletin:

> Why does this magnificent applied science, which saves work and makes life easier, bring so little happiness? The simple answer runs: Because we have not yet learned to make sensible use of it.

LITERATURE CITED

Abraham, S., C. L. Johnson and M. F. Najjar 1976 Height and Weight of Adults 18–74 Years of Age in the United States. Advancedata, No. 3, U.S. Department of Health, Education, and Welfare, Public Health Service, National Center for Health Statistics, Rockville, Maryland.

——— 1977 Weight by Height and Age of Adults 18–74 Years; United States, 1971–1974.

Advancedata, No. 14, U.S. Department of Health, Education, and Welfare, Public Health Service, National Center for Health Statistics, Hyattsville, Maryland.

Australia, Department of Army 1970 Australian Army Anthropometric Survey; Body Dimensions 1970. Headquarters Army Inspection Service, Melbourne, Australia.

Baxter, J. H. 1875 Statistics, Medical and Anthropological, of the Provost Marshal General's Bureau, Derived from Records of the Examination for Military Service in the Armies of the United States during the Late War of the Rebellion, of Over a Million Recruits, Drafted Men, Substitutes and Enrolled Men. 2 volumes. U.S. Government Printing Office, Washington, D.C.

Bolton, C. B., M. Kenward, R. E. Simpson and G. M. Turner 1973 An Anthropometric Survey of 2000 Royal Air Force Aircrew, 1970/1971. Technical Report 73083, Royal Aircraft Establishment, Farnborough, Hants., England. (Also published in 1974 as AGARDograph No. 181, NATO-AGARD, Neuilly sur Seine, France.)

Brues, A. M. 1945 Study of Anthropometric Data. M.I.T.-M.R. No. 166, Chemical Warfare Service Development Laboratory, Massachusetts Institute of Technology, Cambridge, Massachusetts. (ATI 128 658)*

Chapanis, A. (ed.) 1975 Ethnic Variables in Human Factors Engineering. The Johns Hopkins University Press, Baltimore, Maryland.

Chemical Warfare Service 1945 C. W. S. Anthropometric Data on Faces and Heads. C. W. S. Pamphlet No. MIT 1, Chemical Warfare Service Development Laboratory, Massachusetts Institute of Technology, Cambridge, Massachusetts.

Churchill, E., T. Churchill, J. T. McConville and R. M. White 1977 Anthropometry of Women of the U.S. Army-1977; Report No. 2—The Basic Univariate Statistics. Technical Report NATICK/ TR-77/024, U.S. Army Natick Research and Development Command, Natick, Massachusetts. (AD A044 806)

Churchill, E., P. Kikta and T. Churchill 1977 The AMRL Anthropometric Data Bank Library: Volumes I–V. Technical Report AMRL-TR-77-1, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio. (AD A047 314)

Churchill, E., J. T. McConville, L. L. Laubach and R. M. White 1971 Anthropometry of U.S. Army Aviators-1970. Technical Report 72-52-CE, U.S. Army Natick Laboratories, Natick, Massachusetts. (AD 743 528)

Churchill, T., E. Churchill, J. T. McConville and R. M. White 1977 Anthropometry of Women of the U.S. Army-1977; Report No. 3—Bivariate Frequency Tables. Technical Report NATICK/ TR-77/028, U.S. Army Natick Research and Development Command, Natick, Massachusetts. (AD A046 692)

Clauser, C. E., P. Tucker, J. T. McConville, E. Churchill, L. L. Laubach and J. Reardon 1972 Anthropometric Survey of Air Force Women-1968. Technical Report AMRL-TR-70-5, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio. (AD 743 113)

Coblentz, A., and G. Ignazi 1967 Étude Anthropologique de la Main. Anthropologie Appliquée, Document 17/67, Laboratoire d'Anthropologie, Université de Paris, France.

———— 1968 Étude Cephalometrique de Jeunes Francais. Anthropologie Appliquée, Doc. A. A. 22/68 (2 volumes), Laboratoire d'Anthropologie, Université de Paris, France.

Damon, A., C. C. Seltzer, H. W. Stoudt and B. Bell 1972 Age and physique in healthy White veterans at Boston. J. Gerontol., *27:* 202–208.

Damon, A., and H. W. Stoudt 1963 The functional anthropometry of old men. Human Factors, *5:* 485–491.

Damon, A., H. W. Stoudt and R. A. McFarland 1966 The Human Body in Equipment Design. Harvard University Press, Cambridge, Massachusetts.

Daniels, G. S., H. C. Meyers, Jr. and E. Churchill 1953 Anthropometry of Male Basic Trainees. Technical Report WADC-TR-53-49, Aero Medical Laboratory, Wright-Patterson Air Force Base, Ohio. (AD 20 717)

Daniels, G. S., H. C. Meyers, Jr. and S. H. Worrall 1953 Anthropometry of WAF Basic Trainees. Technical Report WADC-TR-53-12, Aero Medical Laboratory, Wright-Patterson Air Force Base, Ohio. (AD 20 542)

* The ATI or AD number following citations of U.S. Armed Forces technical reports is an accession number. Such reports may be purchased in full-size reproductions or in microfiche from: National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22151. NTIS should be contacted for current price information.

Federal Government agencies and their contractors registered with the Defense Documentation Center should direct requests for copies of reports to: Defense Documentation Center, Cameron Station, Alexandria, Virginia 22314. The ATI or AD number should be included when ordering reports.

Davenport, C. B., and A. G. Love 1921 The Medical Department of the United States Army in the World War, Volume 15, Statistics; Part 1, Army Anthropology. U.S. Government Printing Office, Washington, D.C.

Department of the Army 1976 Engineering Design Handbook: Metric Conversion Guide. DARCOM Pamphlet 706-470. Headquarters U.S. Army Materiel Development and Readiness Command. U.S. Government Printing Office, Washington, D.C.

Department of Defense 1974 Military Standard: Human Engineering Design Criteria for Military Systems, Equipment and Facilities. MIL-STD-1472B. U.S. Government Printing Office, Washington, D.C.

———— 1975 Military Standardization Handbook: Human Factors Engineering Design for Army Materiel. MIL-HDBK-759. U.S. Government Printing Office, Washington, D.C.

Diffrient, N., A. R. Tilley and J. C. Bardagjy 1974 Humanscale 1/2/3. The Massachusetts Institute of Technology Press, Cambridge, Massachusetts.

Dobbins, D. A., and C. M. Kindick 1972 Anthropometry of the Latin-American Armed Forces. USATTC Report No. 7209002, U.S. Army Tropic Test Center, Fort Clayton, Canal Zone. (AD 759 949)

Dreyfuss, H. 1955 Designing for People. Simon and Schuster, New York.

———— 1967 The Measure of Man. (2nd ed.) Whitney Library of Design, New York.

Freedman, A., E. C. Huntington, G. C. Davis, R. B. Magee, V. M. Milstead and C. M. Kirkpatrick 1946 Foot Dimensions of Soldiers. Project No. T-13, Armored Medical Research Laboratory, Fort Knox, Kentucky. (AD 658 652)

Garrett, J. W., and K. W. Kennedy 1971 A Collation of Anthropometry. Technical Report AMRL-TR-68-1 (2 volumes), Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio. (AD 723 629 and AD 723 630)

Gifford, E. C. 1960 Compilation of Anthropometric Measures on U.S. Navy Pilots. Report NAMC-ACEL-437, Air Crew Equipment Laboratory, U.S. Naval Air Medical Center, Philadelphia, Pennsylvania. (AD 246 152)

Gifford, E. C., J. R. Provost and J. Lazo 1965 Anthropometry of Naval Aviators-1964. Report NAEC-ACEL-533, Aerospace Crew Equipment Laboratory, U.S. Naval Air Engineering Center, Philadelphia, Pennsylvania. (AD 626 322)

Gooderson, C. Y., and M. Beebee 1976 Anthropometry of Infantrymen 1973–1974. Report APRE 17/76, Army Personnel Research Establishment, Farnborough, Hants., England.

———— 1977 A Comparison of the Anthropometry of 100 Guardsmen with that of 500 infantrymen, 500 RAC Servicemen, and 2000 RAF Aircrew. Report APRE 37/76, Army Personnel Research Establishment, Farnborough, Hants., England.

Gould, B. A. 1869 Investigations in the Military and Anthropological Statistics of American Soldiers. For the U.S. Sanitary Commission. Hurd and Houghton, New York.

Grunhofer, H. J., and G. Kroh (eds.) 1975 A Review of Anthropometric Data of German Air Force and United States Air Force Flying Personnel 1967–1968. AGARDograph No. 205, North Atlantic Treaty Organization, Advisory Group for Aerospace Research and Development (NATO-AGARD). Neuilly sur Seine, France.

Hamill, P. V. V., F. E. Johnston and S. Lemeshow 1973a Height and Weight of Youths 12–17 years, United States. Vital and Health Statistics-Series 11-No. 124, U.S. Department of Health, Education, and Welfare, Public Health Service, National Center for Health Statistics, Rockville, Maryland.

———— 1973b Body Weight, Stature, and Sitting Height: White and Negro Youths 12–17 Years, United States. Vital and Health Statistics-Series 11-No. 126, U.S. Department of Health, Education, and Welfare, Public Health Service, National Center for Health Statistics, Rockville, Maryland.

Hansen, R., and D. Y. Cornog; H. T. E. Hertzberg (ed.) 1958 Annotated Bibliography of Applied Physical Anthropology in Human Engineering. WADC Technical Report 56-30, Aero Medical Laboratory, Wright-Patterson Air Force Base, Ohio. (AD 155 622)

Hart, G. L., G. E. Rowland and R. Malina 1967 Anthropometric Survey of the Armed Forces of the Republic of Korea. (Contract Report, Rowland and Company, Haddonfield, N.J.) Technical Report 68-8-PR, U.S. Army Natick Laboratories, Natick, Massachusetts. (AD 640 891)

Hertzberg, H. T. E., E. Churchill, C. W. Dupertuis, R. M. White and A. Damon 1963 Anthropometric Survey of Turkey, Greece and Italy. AGARDograph 73, Macmillan, New York. (AD 421 428)

Hertzberg, H. T. E., G. S. Daniels and E. Churchill 1954 Anthropometry of Flying Personnel-1950. WADC Technical Report 52-321, Aero Medical Laboratory, Wright-Patterson Air Force Base, Ohio. (AD 47 953)

Hobbs, P. C. 1973 An Anthropometric Survey of 500 Royal Air Force Aircrew Heads, 1972. Technical Report 73137, Royal Aircraft Establishment, Farnborough, Hants., England.

Hooton, E. A. 1945 A Survey in Seating. Heywood-Wakefield, Gardner, Massachusetts.

———— 1959 Body Build in a Sample of the United States Army. (Contract Reports, Harvard University, Cambridge, Mass.). Technical Report EP-102, U.S. Army Quartermaster Research and Engineering Center, Natick, Massachusetts. (AD 214 177)

Human Factors Society Bulletin 1978 *21*:3.

Ince, N. E., S. Redrup and J. Piper 1973 Anthropometry of 500 Royal Armoured Corps Servicemen, 1972. Report APRE 36/73(R), Army Personnel Research Establishment, Farnborough, Hants., England.

Japanese Air Self Defense Force (JASDF) 1972 Anthropometry of JASDF Personnel and its Application for Human Engineering. Aero Medical Laboratory, Japanese Air Self Defense Force, Tokyo, Japan.

Jeffrey, T. E., and L. L. Thurstone 1955 A Factorial Analysis of Foot Measurements. (Contract Report, University of North Carolina, Chapel Hill, N.C.). Technical Report EP-10, U.S. Army Quartermaster Research and Development Center, Natick, Massachusetts. (AD 66 971)

Johnston, F. E., P. V. V. Hamill and S. Lemeshow 1974 Skinfold Thickness of Youths 12–17 Years, United States. Vital and Health Statistics-Series 11-No. 132, U.S. Department of Health, Education, and Welfare, Public Health Service, National Center for Health Statistics, Rockville, Maryland.

Jürgens, H. W., D. Habicht-Benthin und W. Lengsfeld (Anthropologisches Institut der Universität Kiel) 1972 Körpermasse 20-jähriger Männer als Grundlage für die Gestaltung von Arbeitsgerät, Ausrüstung, und Arbeitsplatz. (Zwischenbericht über den Forschungsauftrag BMVg InSan Nr. 2/69). BMVg-FBWM 71-2, Bundesministerium der Verteidigung, Forschungsbericht aus der Wehrmedizin, Dokumentationszentrum der Bundeswehr, Bonn.

Jürgens, H. W., K. Helbig und W. Lengsfeld (Anthropologisches Institut der Universität Kiel) 1973 Körpermasse 25-40 jähriger Männer zur Prüfung der anthropometrisch-ergonomischen Bedeutung altersbedingter Veränderungen der Körperform. (über den Forschungsauftrag BMVg InSan Nr. 3571-V-072). BMVg-FBWM 73-1, Bundesministerium der Verteidigung, Forschungsbericht aus der Wehrmedizin, Dokumentationszentrum der Bundeswehr, Bonn.

Kay, W. C. 1961 Anthropometry of Republic of Korea Air Force pilots. Republic of Korea Air Force Journal of Aviation Medicine, Vol. 9, No. 1, Seoul, Korea.

Kennedy, S. J., and R. M. White 1971 Anthropometric Survey of the Imperial Iranian Armed Forces; Phase III: Technical Summary. U.S. Army Natick Laboratories, Natick, Massachusetts.

Kreifeldt, J. G., and M. M. Ayoub 1976 Directory of Training Programs in Human Factors. (3rd ed.) Human Factors Society, Inc., Santa Monica, California.

Kubokawa, C. (ed.); W. E. Woodson and P. H. Selby 1969 Databook for Human Factors Engineers; Volume I: Human Engineering Data; Volume II: Common Formulas, Metrics, Definitions. (Contract Report, Man Factors Inc., San Diego, Calif.). CR114271 and CR114272, National Aeronautics and Space Administration, NASA-Ames Research Center, Moffet Field, California.

Laubach, L. L., J. T. McConville, E. Churchill and R. M. White 1977 Anthropometry of Women of the U.S. Army-1977; Report No. 1-Methodology and Survey Plan. Technical Report NATICK/TR-77/021, U.S. Army Natick Research and Development Command, Natick, Massachusetts. (AD AO43 715)

McCallum, D., and R. Henderson 1969 Foot Survey of Indigenous Soldiers of Papua/New Guinea. A.A.O.R.G. Report 1/69, Australian Army Operational Research Group, Melbourne, Australia.

McCann, C., I. Noy, B. Rodden and O. Logan 1975 1974 Anthropometric Survey of Canadian Forces Personnel. DCIEM Report No. 75-R-1114, Defence and Civil Institute of Environmental Medicine, Downsview, Ontario, Canada.

Maclean, A. J. 1968 Anthropometric Survey; Australian Army Foot Dimensions 1968. Headquarters Army Inspection Service, Melbourne, Australia.

McConville, J. T., E. Churchill, T. Churchill and R. M. White 1977 Anthropometry of Women of the U.S. Army-1977; Report No. 5-Comparative Data for U.S. Army Men. Technical Report NATICK/TR-77/029, U.S. Army Natick Research and Development Command, Natick, Massachusetts. (AD AO48 591)

McFarland, R. A., A. Damon, H. W. Stoudt, A. L. Moseley, J. W. Dunlap and W. A. Hall 1953 Human Body Size and Capabilities in the Design and Operation of Vehicular Equipment. Harvard School of Public Health, Boston, Massachusetts.

Malina, R. M., P. V. V. Hamill and S. Lemeshow 1973 Selected Body Measurements of Children 6–11 Years, United States. Vital and Health Statistics-Series 11-No. 123, U.S. Department of

Health, Education, and Welfare, Public Health Service, National Center for Health Statistics, Rockville, Maryland.

———— 1974 Body Dimensions and Proportions, White and Negro Children 6–11 Years. Vital and Health Statistics-Series 11-No. 143, U.S. Department of Health, Education, and Welfare, Public Health Service, National Center for Health Statistics, Rockville, Maryland.

Martin, J. I., R. Sabeh, L. L. Driver, T. D. Lowe, R. W. Hintze and P. A. C. Peters 1975 Anthropometry of Law Enforcement Officers. Technical Document 442, Naval Electronics Laboratory Center, San Diego, California. (AD AO17 066)

Morgan, C. T., J. S. Cook, III, A. Chapanis and M. W. Lund (eds.) 1963 Human Engineering Guide to Equipment Design. McGraw-Hill, New York.

Morrison, J. F., C. H. Wyndham, N. B. Strydom, J. J. Bettencourt and J. H. Viljoen 1968 An anthropometrical survey of Bantu mine labourers. J. of the S. Afr. Inst. Mining and Metallurgy, *January, 1968:* 275–279.

Newman, R. W., and R. M. White 1951 Reference Anthropometry of Army Men. Report No. 180, U.S. Army Quartermaster Climatic Research Laboratory, Lawrence, Massachusetts. (AD 149 451)

Noorani, Shoja-eddin, and C. N. Dillard, Jr. 1970 Anthropometric Survey of the Imperial Iranian Armed Forces; Volume I: Data Collection and Analysis; Volume II: Statistical Data. Technical Report of the Combat Research and Evaluation Center; Imperial Iranian Ground Forces, Teheran, Iran. (AD AO35 649 and AD AO35 650)

O'Brien, R. 1930 An Annotated List of Literature References on Garment Sizes and Body Measurements. Miscellaneous Publication No. 78, U.S. Department of Agriculture, Bureau of Home Economics. U.S. Government Printing Office, Washington, D.C.

O'Brien, R., M. A. Girshick and E. P. Hunt 1941 Body Measurements of American Boys and Girls for Garment and Pattern Construction. Miscellaneous Publication No. 366, U.S. Department of Agriculture, Bureau of Home Economics. U.S. Government Printing Office, Washington, D.C.

O'Brien, R., and W. C. Shelton 1941 Women's Measurements for Garment and Pattern Construction. Miscellaneous Publication No. 454, U.S. Department of Agriculture, Bureau of Home Economics. U.S. Government Printing Office, Washington, D.C.

Oshima, M., T. Fujimoto, T. Oguro, N. Tobimatsu, T. Mori, I. Tanaka, T. Watanabe and M. Alexander (USAF) 1962 Anthropometry of Japanese Pilots. Reports of the Aero Medical Laboratory, Vol. 2, No. 2, Tokyo, Japan.

Owings, C. L., D. B. Chaffin, R. G. Snyder and R. H. Norcutt 1975 Strength Characteristics of U.S. Children for Product Safety Design. (Contract FDA-73-32; prepared for the Consumer Product Safety Commission). University of Michigan, Ann Arbor, Michigan.

Randall, F. E., A. Damon, R. S. Benton and D. I. Patt 1946 Human Body Size in Military Aircraft and Personal Equipment. Army Air Forces Technical Report 5501, Air Material Command, Wright Field, Dayton, Ohio. (ATI 25 419)

Randall, F. E., and E. H. Munro 1949 Reference Anthropometry of Army Women. Report No. 149, U.S. Army Quartermaster Climatic Research Laboratory, Lawrence, Massachusetts. (AD 209 837)

Reid, B. 1976 An Annotated Bibliography of United States Air Force Applied Physical Anthropology—January 1946 to July 1976. Technical Report AMRL-TR-76-58, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio. (AD AO29 942)

Reynolds, H. M., and M. A. Allgood 1975 Functional Strength of Commercial Airline Stewardesses. Report No. FAA-AM-75-13, Federal Aviation Administration, Civil Aeromedical Institute, Oklahoma City, Oklahoma.

Roebuck, J. A., Jr., K. H. E. Kroemer and W. G. Thomson 1975 Engineering Anthropometry Methods. John Wiley and Sons, New York.

Ronco, P. G., and project staff 1966–1967 Human Factors Engineering Bibliographic Series; Volume 1: 1940–1959 Literature (1966); Volume 2: 1960–1964 Literature (1966); Volume 3: 1965 Literature (1967); Volume 4: 1966 Literature (1967). (Prepared by Human Factors Engineering Information Analysis Center, Tufts University, Medford, Mass.). U.S. Army Human Engineering Laboratories, Aberdeen Proving Ground, Maryland.

Sahley, L. W. 1957 Dimensions of the Human Figure. Cleveland Designers and Consultants, Inc., Cleveland, Ohio.

Schane, W. P., D. E. Littell and C. G. Moultrie 1969 Selected Anthropometric Measurements of 1640 U.S. Army Warrant Officer Candidate Flight Trainees. USAARL Report No. 69-2, U.S. Army Aeromedical Research Laboratory, Fort Rucker, Alabama. (AD 688 856)

Snow, C. C., H. M. Reynolds and M. A. Allgood 1975 Anthropometry of Airline Stewardesses.

Report No. FAA-AM-75-2, Federal Aviation Administration, Civil Aeromedical Institute, Oklahoma City, Oklahoma.

Snow, C. C. and R. G. Snyder 1965 Anthropometry of Air Traffic Control Trainees. Federal Aviation Agency, Civil Aeromedical Research Institute, Oklahoma City, Oklahoma.

Snyder R. G., L. W. Schneider, C. L. Owings, H. M. Reynolds, D. H. Golomb and M. A. Schork 1977 Anthropometry of Infants, Children, and Youths, to Age 18 for Product Safety Design. (Prepared for the Consumer Product Safety Commission). Report No. UM-HSRI-77-17, Highway Safety Research Institute, University of Michigan, Ann Arbor, Michigan.

Snyder, R. G., M. L. Spencer, C. L. Owings and L. W. Schneider 1975 Physical Characteristics of Children as Related to Death and Injury for Consumer Product Safety Design. (Prepared for the Consumer Product Safety Commission). Report No. UM-HSRI-BI-75-5, Highway Safety Research Institute, University of Michigan, Ann Arbor, Michigan.

Snyder, R. G., M. L. Spencer, C. L. Owings and P. Van Eck 1972 Source Data of Infant and Child Measurements; Interim Data, 1972. (Prepared for the Food and Drug Administration). Highway Safety Research Institute, University of Michigan, Ann Arbor, Michigan.

Society of Automotive Engineers 1968 The Range of Anthropometric Measurements for Asian Populations. SAE J317. Society of Automotive Engineers, Inc., New York.

Staples, M. L. 1964 A Bibliographical Survey and Critical Review of the Role of Anthropometry in the Sizing of Clothing and Personal Equipment. (Prepared by the Ontario Research Foundation, Toronto). Defence Research Board, Ottawa, Canada.

Steinberg, H. L. 1974 Development of a National Anthropometric Data Base: a Preliminary Study Report. NBSIR 74-506, Institute for Applied Technology, National Bureau of Standards, Washington, D.C.

Stoudt, H. W. 1961 The Physical Anthropology of Ceylon. The Colombo Museum, Colombo, Ceylon.

Stoudt, H. W., T. J. Crowley, R. A. McFarland, A. Ryan, B. Gruber and C. Ray 1970 Static and Dynamic Measurements of Motor Vehicle Drivers. (Contract FH-11-6569, prepared for the National Highway Safety Bureau). Harvard School of Public Health, Boston, Massachusetts.

Stoudt, H. W., A. Damon, R. A. McFarland and J. Roberts 1965 Weight, Height, and Selected Body Dimensions of Adults United States, 1960–1962. Public Health Service Publication No. 1000-Series 11-No. 8, U.S. Department of Health, Education, and Welfare, Public Health Service, National Center for Health Statistics, Washington, D.C.

———— 1970 Skinfolds, Body Girths, Biacromial Diameter, and Selected Anthropometric Indices of Adults United States, 1960–1962. Public Health Service Publication No. 1000-Series 11-No. 35, U.S. Department of Health, Education, and Welfare, Public Health Service, National Center for Health Statistics, Washington, D.C.

Strydom, N. B., J. F. Morrison, C. H. van Graan, J. H. Viljoen and A. J. A. Heyns 1968 Functional anthropometry of White South African males. S. Afr. Med. J., *42:* 1332–1335.

Time Magazine, *January 2, 1978,* p. 53.

Toulson, P. K. 1974 Anthropometric Survey of RNZAF Aircrew. Report No. AMU 3/74, Aviation Medicine Unit, Royal New Zealand Air Force, Auckland, New Zealand.

Van Cott, H. P., and R. G. Kinkade (eds.) 1972 Human Engineering Guide to Equipment Design. (Revised ed.). U.S. Government Printing Office, Washington, D.C.

Webb, P. (ed.) 1964 Bioastronautics Data Book. National Aeronautics and Space Administration, Washington, D.C.

White, R. M. 1961 Anthropometry of Army Aviators. Technical Report EP-150, U.S. Army Quartermaster Research and Engineering Center, Natick, Massachusetts. (AD 263 357)

———— 1964a Anthropometric Survey of the Royal Thai Armed Forces. (For the Advanced Research Projects Agency). U.S. Army Natick Laboratories, Natick, Massachusetts. (AD 450 836)

———— 1964b Anthropometric Survey of the Armed Forces of the Republic of Vietnam. (For the Advanced Research Projects Agency). U.S. Army Natick Laboratories, Natick, Massachusetts. (AD 458 864)

———— 1977 An Annotated Bibliography of U.S. Army Anthropology (1947–1977). Technical Report NATICK/TR-78/012, U.S. Army Natick Research and Development Command, Natick, Massachusetts.

White, R. M., and E. Churchill 1971 The Body Size of Soldiers; U.S. Army Anthropometry—1966. Technical Report 72-51-CE, U.S. Army Natick Laboratories, Natick, Massachusetts. (AD 743 465)

———— 1977 United States Marine Corps Anthropometry. Technical Report NATICK/TR-78/021, U.S. Army Natick Research and Development Command, Natick, Massachusetts. (in press)