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Anthropometric Source Book
Volume III: Annotated Bibliography
of Anthropometry

Edited by
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PREFACE

The Anthropometric Source Book is designed to provide NASA, NASA contractors, the aerospace industry, Government agencies, and a wide variety of industrial users in the civilian sector with a comprehensive, up-to-date tabulation of anthropometric data. Specifically, it is tailored to meet the needs of engineers engaged in the design of equipment, habitability areas, workspace layouts, life-support hardware, and clothing for the NASA Space Shuttle/Spacelab program. The intent is to provide the designer not only with dimensional data but with underlying anthropometric concepts and their application to design.

All available anthropometric data collected in the weightless environment are documented in this three-volume book, which also includes an extensive tabulation of anthropometric data defining the physical size, mass distribution properties, and dynamic capabilities of U.S. and selected foreign populations. The material covers adult males and females of various age groups, socio-educational backgrounds, races, and ethnic backgrounds. Also included are size-range projections for a 1985 population eligible for manned space flight.

Volume I is a nine-chapter treatment covering all basic areas of anthropometry and its applications to the design of clothing, equipment, and workspaces.

Chapter 1, "Anthropometric Changes in Weightlessness," addresses the effects on the human body that occur as a result of weightlessness. Such topics as weight loss, height increases, neutral body posture, strength and body composition, changes in trunk and limb girth, and loss of muscle mass are discussed in detail. In addition to bringing together in a single source the most comprehensive collection of data on anthropometric change in weightlessness that exists in this country, this chapter calls attention to the potential impact of weightlessness on man/machine design and suggests areas of future study essential to the proper design of man's space environment.

Chapter 2, "Variability in Human Body Size," describes and graphically documents the range of human-body variability found among homogeneous groups. Those trends that show significantly marked differences between sexes and among a number of racial/ethnic groups are also presented. This chapter alerts design engineers to the nature and extent of human-body variability and serves as a guide for modifying and designing man/machine systems.

Chapter 3, "Anthropometry," presents tabulated dimensional anthropometric data on 59 variables for 12 selected populations. The variables chosen were judged most relevant to current manned space programs. Appendix A to this chapter is a glossary of anatomical and anthropometric terms. Appendix B covers selected body dimensions of males and females from the potential astronaut population projected to the 1980-1990 time frame. Appendix C contains a 5th-, 50th-, and 95th-percentile drawing-board manikin based on the anticipated 1980-1990 body-size distribution of USAF fliers.

Chapter 4, "The Inertial Properties of the Body and Its Segments," is a user-oriented summary of the current state of knowledge on the mass distribution properties of the adult human body. The data presented lend themselves to mathematical modeling.

Chapter 5, "Arm-Leg Reach and Workspace Layout," is an informative chapter on functional reach measurements relevant to the design and layout of workspaces. Basic reach data are given, along with recommendations for applying corrective factors to adjust for differences in (1) workspace, task, and body position; (2) environmental conditions - primarily gravity forces; and (3) anthropometric characteristics of various populations.

Chapter 6, "Range of Joint Motion," discusses (1) selected reviews of the range-of-joint-motion literature; (2) techniques for measuring range of joint motion; (3) range-of-joint-motion terminology; (4) recommended range-of-joint-motion data for the design engineer; (5) differences in the range of joint motion due to the effects of age, sex, and protective clothing; and (6) the range of joint motion of selected two-joint muscles. Together, chapters 5 and 6 constitute a comprehensive data base and guide to workstation layout.

Chapter 7, "Human Muscular Strength," deals with (1) a general review of human muscular strength, (2) specificity of muscular strength, (3) relationships between static and dynamic muscular strength, (4) strength within the arm reach envelope of the seated subject, and (5) comparative muscular strength of men and women. This chapter should aid design engineers in relating strength data to workspace design.

Chapter 8, "Anthropometry in Sizing and Design," discusses the application of human body-size diversity and quantification to engineering design. Procedures are outlined for using anthropometric data in the development of effective sizing programs.

Chapter 9, "Statistical Considerations in Man/Machine Design," reviews statistical concepts that appear repeatedly in the NASA Anthropometric Source Book and touches on some statistical problems that will typically confront individuals using the data.

Volume I was compiled and edited by the following members of the Anthropology Research Project of Webb Associates, Yellow Springs, Ohio: Edmund Churchill, Lloyd L. Laubach, John T. McConville, and Ilse Tebbetts.

Volume II summarizes the results from anthropometric surveys of 61 military and civilian populations of both sexes from the United States, Europe, and Asia. Some 295 measured variables are defined and illustrated. The variable names are listed in alphabetical order. For each variable, there is a computer order number by which it is identified, a list of surveys in which it was measured, a group of summary statistics, and a series of values for the 1st, 5th, 10th, 25th, 50th, 75th, 90th, 95th, and 99th percentile of the given population.

Preceding the presentation of the actual data are three indexes designed to assist the reader in the use of the material. The first of these indexes, entitled "Anthropometric Surveys: A Reference List," lists and describes the sources from which all the summary data in this volume were extracted. This enables the user to obtain additional information on any survey population if that is desired. The next index, entitled "Definition of Measurements," includes both written descriptions of all the variables cited and simplified line drawings, where feasible, to illustrate a particular measurement. The third index is provided to further guide the user in identifying and finding measurements relevant to his or her particular needs. It is entitled "Index of Dimensions." The variables are listed by name and are categorized by anatomical region and by anthropometric technique.

Volume II contains a minimum of text-type material and is primarily a handbook of tabulated dimensional anthropometric data. It is probably the most comprehensive source of summarized body-size data currently in existence.

Volume II was compiled and edited by the following members of the Anthropology Research Project of Webb Associates, Yellow Springs, Ohio: Edmund Churchill, Thomas Churchill, Kay Downing, Peggy Erskine, Lloyd L. Laubach, and John T. McConville.

Volume III lists 236 annotated references related to the field of anthropometry. Included are references to every anthropometric survey outlined in volume II, as well as a variety of other works on static and working anthropometry of U.S. and foreign populations, anthropometry of parts of the body related to the design of specific items such as gloves or helmets, joint range and arm reach, mass distribution properties of the body, strength data of various kinds, sizing systems, material on zero gravity, and some general reference works. The references listed were selected by the editors and contributors to volume I. Their objective was to reference those studies, reports, textbooks, and surveys that they deemed most related to their specific subject area and that would be most helpful to the user.

Volume III was compiled and edited by the following members of the Anthropology Research Project of Webb Associates, Yellow Springs, Ohio: Lloyd L. Laubach, John T. McConville, and Ilse Tebbetts.

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INTRODUCTION

This volume contains 236 annotated references intended as a guide to salient studies, surveys, textbooks, reports and classic works in the field of anthropometry. It is, of course, impossible to compile a completely exhaustive bibliography on any subject as complex as this one. The object of the selection process, which has been the joint effort of the editors and contributors, has been to compile, in depth, reports of basic anthropometric measurement data and to cover broadly as much allied subject matter as was deemed useful. Thus, we have included references to every anthropometric survey outlined in Volume II as well as a variety of other works on static and working anthropometry of U.S. and foreign populations, anthropometry of parts of the body related to the design of specific items such as gloves or helmets, joint range and arm reach material, studies and reports covering the mass distribution properties of the body, strength data of various kinds, articles on sizing systems, material on zero-gravity and some general reference works. Finally, we have included four additional annotated bibliographies intended to expand the scope of this volume. These are:

Brown, John R. 1972. Manual Lifting and Related Fields: An Annotated Bibliography.

Hansen, Robert and Douglas Cornog. 1958. Annotated Bibliography of Applied Physical Anthropology in Human Engineering.

Staples, M. L. 1961. A Bibliographical Survey and Critical Review of the Role of Anthropometry in the Sizing of Clothing and Personal Equipment.

Thiberg, Sven et al. 1965. Anatomy for Planners I: List of Literature.

A large number of the annotations included in this volume are adaptations of bibliographic summaries which appear in An Annotated Bibliography of United States Air Force Applied Physical Anthropology January 1946 to May 1973, compiled by Betty Reid (1976) of the Aerospace Medical Research Laboratory, Wright Patterson Air Force Base, O. This document has not been included here as a separate reference only because we have covered so much of the same ground.

Our objectives in writing these annotations or adapting them from authors' abstracts have been: (1) to make them as clear and comprehensible as possible by eliminating highly specialized jargon; (2) to include relevant material of practical use to NASA design engineers, and (3) to suggest, where possible, specific design applications of the data described.

Both the author's index and the key word index are intended to help the reader use this bibliography selectively to find source material of particular interest to him or of specific relevance to his design problem. Entries in this volume are listed alphabetically by senior author and numbered for reference purposes in the use of the two indexes. Thus, in looking up an author or a topic such as "range of motion", the numbers which appear after the author or topic refer to those numbers assigned to each entry rather than to page numbers.

1. Alexander, Milton and Charles E. Clauser. Anthropometry of Common Working Positions.

AMRL-TR-65-73, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 24 pages, 16 references, 1965. (AD 632 241)

Twenty-six dimensions of the human body in various working positions were obtained by photography or by direct measurement. Fifty-three male subjects, representative of the USAF population as surveyed in 1950, were directly measured standing, stooping, kneeling, squatting and supine. In addition, photogrammetry was used to obtain selected envelope dimensions of the body and the feet; two hundred thirty one sample slides chosen for this portion of the study were selected from a larger series of 2,225 subjects photographed in the 1957 USAF antropometric survey.

Purpose of this study was to provide data for human engineers designing work stations for men working in cramped areas.

2. Alexander, Milton, John W. Garrett and Michael P. Flannery. Anthropometric Dimensions of Air Force Pressure-Suited Personnel for Workspace and Design Criteria.

AMRL-TR-69-6, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 257 pages, 23 references, 1969. (AD 697 022)

The results of an anthropometric survey of USAF personnel wearing the A/P22S-2 Full Pressure Suit fitted in accordance with the USAF eight-size height-weight sizing program are presented. One hundred and thirty-eight measures were taken on each of 34 subjects standing, sitting, and supine, with the suit in the uninflated, inflated and inflated-restrained conditions. Forty circumferences were measured on a separate sample of 32 subjects standing and sitting, with the suit uninflated and inflated. Pictorial and verbal descriptions of the dimensions and detailed numerical results, including clearance ranges, are presented. Graphs comparing various dimensions across suit sizes are presented in the Appendix. Subjects were USAF military personnel chosen to represent a cross section of the entire USAF population.

The body dimensions and workspace clearance values in this report were selected to meet the needs of engineers who design workspace areas for high-altitude aerospace vehicles in which pressure-suited aircrewmembers must function in a variety of positions.

3. Alexander, Milton, Robert S. Zeigen and Irvin Emanuel. "Anthropometric Data Presented in Three-Dimensional Forms."

American Journal of Physical Anthropology, 19:147-157, 18 references, 1961.

This article describes various efforts to translate anthropometric data into three-dimensional forms for purposes of designing close-fitting protective equipment. The development of three sets of forms, all employing key dimensions, are described in detail: (1) a series of face forms using face length and lip length for the design of oxygen masks, (2) two series of head forms using head circumference for the design of helmets and, (3) a series of body manikins based on height and weight for the design of pressure suits. The design rationale and difficulties encountered in sculpturing these forms are discussed.

4. Alexander, Milton and Lloyd L. Laubach. Anthropometric Dimensions of the Human Ear (A Photogrammatic Study of USAF Flight Personnel).

AMRL-TR-67-203, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 28 pages, 13 references, 1968. (AD 670 869)

A technique was developed which enables precisely specified ear dimensions to be measured directly from PhotoMetric slides. Summary statistics for each of the ear dimensions are presented for a sample of 500 subjects randomly chosen from a series of 2,236 photographic slides collected during the 1957 Anthropometric Survey of USAF male flying personnel. Regression equations for predicting the various tragus radii angular measurements from the measurements of ear length and ear breadth are presented and a complete intercorrelation matrix for all variables studied is shown. The reliability and objectivity of the technique is discussed.

Data in this study should be of use to designers of protective head-gear in which ill-fitting earcups often result in pain or discomfort which increases with the passage of time.

5. Alexander, Milton and H. T. E. Hertzberg. A Comfort Evaluation of a Form-Fitting High Altitude Helmet.

WADC-TR-56-404, Wright Air Development Center, Wright Patterson Air Force Base, O., 15 pages, 1957. (AD 110 548)

This report describes comfort tests on an experimental pressure helmet assembly consisting of an outer rigid shell and an inner compressible form-fitting liner of polyurethane foam. The 72 subjects used in the study included 21 pilots and 51 airmen. A number of testing techniques and fabrication requirements for comfort and acceptability are discussed and their applicability to most forms of headgear, especially that using compressible liner material, is indicated.

6. Alexander, Milton, John T. McConville, James H. Kramer and Eugene Fritz. Height-Weight Sizing of Protective Garments, Based on Japanese Air Self-Defense Force Pilot Data with Fit-Test Results.

AMRL-TDR-64-66, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 33 pages, 12 references, 1964. (AD 606 039)

This report discusses the development and test of a four-size height-weight sizing program of partial pressure and exposure suits designed for the Japanese Air Self-Defense Force. The sizing program is based on an anthropometric survey of 239 subjects conducted at five air bases throughout Japan during the spring of 1961. The statistical rationale used in devising the height-weight program is presented along with the analysis of the anthropometric data. Two garments, the GSU-7/P Partial Pressure Assembly and the CWU-13/P Exposure Garment, were fabricated in accordance with the developed sizing program. A fit-test of these garments was conducted on 75 Japanese pilots at Hamamatsu and Tachikawa Air Bases in Japan in April, 1963. Results of the fit-tests served to validate the soundness of the basic survey data and subsequent development of the height-weight sizing program.

7. American Academy of Orthopaedic Surgeons, Members of the Committee for the Study of Joint Motion. Joint Motion--Method of Measuring and Recording.

American Academy of Orthopaedic Surgeons, 430 North Michigan Ave., Chicago, Ill. 60611, 87 pages, 17 references, 1965.

This booklet is a very useful elementary publication describing various aspects of range of joint motion. Sections of the booklet deal with principles of measuring joint motion, types of motion, use of the goniometer, the measurement of joints, and average ranges of joint motion. The booklet was prepared for usage by practicing clinical orthopaedic surgeons. A table of the average range of joint motion for the body segments of the elbow, forearm, wrist, thumb, fingers, shoulders, hip, knee, ankle, foot, toes, and the spine is of use to the design engineer.

8. Andrae, B., J. Ekmark and H. Laestadius. Anthropometry of Flying Personnel in the Royal Swedish Air Force.

Library Translation No. 1502, Royal Aircraft Establishment, Farnborough, Hants, England, 56 pages, 36 references, 1971.

The authors analyze the results of an anthropometric survey of 240 flying personnel divided into three age groups (born in 1925-7, 1939-40, and 1944) and conclude, in conjunction with data on stature of Swedish conscripts obtained during the last century, that Swedish pilots have been increasing in stature at the rate of about one cm. per decade.

Data is graphed and tabulated in various ways to show comparisons among the three groups on some 15 measurements relevant to cockpit design. A table showing the range of presently authorized requirements for body measurements of Swedish flying personnel is given at the beginning of the report. Because the data suggest a slow growth in almost every dimension measured, as reflected by differences in the three subject groups, the authors present a table of proposed requirements for the year 1980.

9. Anonymous. Australian Army Anthropometric Survey: Body Dimensions 1970.

Headquarters, Army Inspection Service, Melbourne, Australia, 24 pages, 1970.

Twenty-six measurements were taken on each of 3,695 subjects representative of a typical cross-section of Australian military personnel. Data is presented in distribution graphs and in bivariate tables of selected dimensions.

Purpose of this survey was to determine the range of sizes of clothing required for the Australian Armed Forces and to guide clothing design and research.

10. Anonymous. Etude Anthropometrique des Personnels Militaires des Armees (in French).

Anthropologie Appliquee, 45 rue des Saints-Peres, Paris, 6e, France, 1,167 pages, 1973.

This report presents in detail results of a survey of 1,272 French military subjects from the Army, the Air Force and the Navy. A total of 214 measurements were made, many duplicated on unclothed and fully equipped subjects. Emphasis in selecting dimensions to be measured was on functional anthropometry for application in the design of workspaces. Results are presented in summary statistics, percentile tables and distribution graphs. Differences between dimensions measured on naked and clothed subjects are tabulated.

The subject population and subseries, based on branch of service and rank, are analyzed for sociological, education and geographical background.

11. Anonymous. Human Engineering Criteria for Maintenance and Repair of Advanced Space Systems, Volumes I through IV.

General Electric Space Division, Valley Forge Space Center, Philadelphia, Pa., 703 pages, 1969.

The purpose of this research was to obtain human engineering criteria in a simulated zero-gravity environment which could be used for the design of advanced space systems. The results of three experiments are reported. The first defined access reach envelopes as a function of different body restraint systems under shirtsleeve and pressure suit conditions. The second study determined the time required to perform manual manipulation tasks as a function of module size, mass and location, and body restraint system under pressure suit conditions. The third determined the ability to perform motor functions in the reach envelopes previously defined as a function of body restraint systems and shirtsleeve and pressure suit conditions. Zero-gravity was simulated by under water neutral buoyancy testing conditions. Four subjects were tested. The data are presented in tabular and graphic form.

In the absence of true zero-g reach studies, the data are quite useful as indicators of the kinds of body movement and performance that might be anticipated under such conditions.

12. Anonymous. "Increase in Stature of American Men."

Statistical Bulletin #25, Metropolitan Life Insurance Co., 2 pages, 1944.

This brief article reports on secular changes in stature of American men between the First and Second World Wars. Findings show that inductees in WWII averaged two thirds of an inch taller than their counterparts in 1917. Further findings indicate that the proportion of taller men (six feet and over) in the studied samples was about one third greater in 1943 than in 1917.

Supplementary data on the height of Canadian school children is cited to confirm the trend toward increased stature by showing that the typical six-year-old was some two inches taller in 1939 than a child of the same age in 1892. Increases are attributed to improved nutrition and better general health.

13. Anonymous. "Is the Average Height of American Women Increasing?"

Statistical Bulletin, Metropolitan Life Insurance Co., 2 pages, 1938.

The article concludes that the average height of American women is probably increasing although data tends to be conflicting. Various studies of college women show clear evidence of "growth" from generation to generation; another study cited showed that native-born women of immigrant parents tended to be taller than their parents. At the same time, analysis of data collected from women accepted for general insurance between 1922 and 1934 showed heights identical to those measured in two earlier periods (1900-1908 and 1909-1927). A second study of women insured by Metropolitan showed a trend toward shrinking stature among the older women in the sample. Results from the latter two studies, however, may be explained by the influx of shorter Southern and Eastern Europeans into the American population in the earlier part of this century. Thus the increased percentage of the shorter ethnic stock in the total population may well have nullified an increase in the combined averages.

14. Anonymous. RAAF Anthropometry Survey.

Report No. TS 1614, Royal Australian Air Force, Aircraft Research & Development Unit, Laverton, Australia, 131 pages, 10 references, 1973.

This document reports results of an anthropometric survey of RAAF aircrew subjects which included 97 cadets and 385 trained aircrew subdivided into five categories according to assignment. Eighteen dimensions were measured.

Summary statistics are given as well as histograms showing the distribution of values for each measurement for each sub-group. Comparison with similar surveys of USAF and RAAF aircrew yielded few meaningful differences among the three populations.

15. Anonymous. RCAF Anthropometrical Survey.

Defense Documentation Center, Defense Supply Agency, Cameron Station, Alexandria, Va., 18 pages, 1961-62. (AD 809 424)

The purpose of this anthropometric survey of Royal Canadian Air Force personnel (314 pilots and 290 navigators) was to determine the correlation between results obtained by British and American measuring techniques. It is included here, not for that purpose, but because it is one of the few documents recording anthropometric data of Canadians.

Sixty-eight dimensions were measured and results given here in percentile tables.

16. Ashe, William F., Lester B. Roberts and Paul Bodenman. Anthropometric Measurements.

Project No. 9, File No. 741-3, Armored Force Research Laboratory, Fort Knox, Ky., 37 pages, 1943.

This report consists chiefly of tables showing the results of anthropometric measurements made on 900 Armored Force School soldiers or on 2,959 Air Force personnel known to resemble Armored Force personnel. Data is presented in terms of percentile distributions.

The measurements were selected for their use in the design of equipment, particularly armored vehicles such as tanks in which space limitations are a major factor.

17. Asmussen, Erling, and K. Keeboll-Nielsen. "Isometric Muscle Strength of Adult Men and Women."

Communications from the Testing and Observation Institute of the Danish National Association for Infantile Paralysis, Hellerup, Denmark, No. 11, 43 pages, 3 references, 1961.

The isometric muscle strength of 360 men (aged 15 to 65) and 250 women (aged 15 to 55) were measured for 25 different muscle groups. The average value for all women, except the 15-20 year olds, was found to be only 58 to 66% of that of men of corresponding age. Even when corrections were made for lower body height of women (since a positive relationship between height and strength was demonstrated) women's muscular strength was found to be no more than 70 to 80% of that of men of the same age. Maximum muscle strength was reached sooner in women but was shown to decrease at an earlier age although investigators found characteristic differences between different muscle groups in this respect.

Detailed results are presented in a series of tables in which the average measured strength for each muscle group is calculated for a range of ages and heights for men and women.

18. Asmussen, Erling, Ole Hansen and Ole Lammert. "The Relation Between Isometric and Dynamic Muscle Strength in Man."

Communications from the Testing and Observation Institute of the Danish National Association for Infantile Paralysis, Hellerup, Denmark, No. 20, 11 pages, 7 references, 1965.

A series of muscle tests were performed on 18 men aged 18-30 years. Maximal contractions were performed with the arm-shoulder muscles pulling on a handle (1) under isometric conditions, (2) during shortening of the muscles (lifting) and (3) during lengthening of the muscles (lowering).

There was a high degree of correlation between a subject's isometric strength as measured by (1) above and his dynamic strength as measured by (2) and (3). The results were independent of athletic fitness which varied among the subjects.

Specifically it was found that maximum force is likely to be somewhat less during lifting than during isometric contractions and somewhat more during lowering than during isometric contractions.

19. Ayoub, M. M. "Human Movement Recording for Biomechanical Analysis."

International Journal of Production Research, 10:35-51, 32 references, 1972.

Three relatively low-cost systems for the recording and quantification of human motion are described and evaluated. Covered in the discussion are (1) the accelerometer system, (2) the potentiometric system and (3) the stereophotogrammatic system. The latter, according to the author, appears to have considerable potential.

Research leading to the development of equations describing human upper extremity movement is presented. Finally, possible applications and new techniques in human movement recording are discussed.

20. Ayoub, M. M. and J. W. McDaniel. "Effects of Operator Stance on Pushing and Pulling Tasks."

AIIE Transactions, 6:185-195, 21 references, 1974.

Thirty-five male and 11 female students, selected at random, were used as subjects in an experiment designed to determine maximum isometric pushing and pulling forces as a function of the stance of the operator. Results showed that the placement of the rear foot during pushing, the front foot in the case of pulling, and the location of the hands in applying the force have a significant effect on pushing and pulling forces. Body weight and height also have significant effects.

Specific positions of hands (in terms of distance from the floor) and feet (in terms of distance away from the plane of force application) are suggested to achieve optimum effectiveness in applying forces. It is recommended that equipment requiring such forces be designed so as to be functional when the operator assumes the suggested positions.

21. Bachrach, Arthur, Glen H. Egstrom and Susan M. Blackmun. "Biomechanical Analysis of the U.S. Navy Mark V and Mark XII Diving Systems."

Human Factors, 17:328-336, 5 references, 1975.

The primary objective of this study was to compare range of joint motion data obtained from a sample of six male, professional divers under five different experimental conditions. Subjects' heights, weights and ages were representative of the Navy first-class diver population. Each subject served as his own control with baseline measurements taken in a swim suit and then the subjects were measured wearing the Mark V and Mark XII diving systems, both on dry land and in water. Fourteen range of joint motion measurements that pertained to movements of the shoulder, elbow, hip, knee and trunk were obtained from each subject in the five experimental conditions.

The overall conclusion of this study was that the mean loss of mobility, both in wet and in dry modes, indicated that the Mark XII system was superior to the Mark V system.

22. Backlund, L. and L. Nordgren. "A New Method for Testing Isometric Muscle Strength Under Standardized Conditions."

Scandinavian Journal of Clinical and Laboratory Investigation, 21:33-41, 7 references, 1968.

The major portion of this paper is concerned with the description of an apparatus to measure static muscle strength. The author reports descriptive data for 34 muscle strength measurements and compares them with previously published data. The subjects were 25 young Swedish males averaging about 22 years old.

23. Baker, P., J. M. McKendry and G. Grant. Anthropometry of One-Handed Maintenance Actions.

TR NAVTRADEVGEN 330-1-3, U.S. Naval Training Device Center, Port Washington, N.Y., 34 pages, 7 references, 1961.

Four basic types of dynamic maintenance actions were isolated: turn-screwdrivers and spinites; grasping, removing and replacing plug-in units; grasping, turning and cutting with pliers and wirecutters; and turning wrenches.

Six subjects whose hands were in the 95th percentile in length and breadth were measured in the execution of 13 separate tasks encompassing the above-mentioned basic motions. The data was acquired photographically and space envelopes required for each task measured and tabulated.

24. Barkla, D. "The Estimation of Body Measurements of British Population in Relation to Seat Design."

Ergonomics, 4:2, 123-132, 20 references, 1961.

This article brings together the principal published information on those human dimensions relevant to seat design. Although the paper was written for use by British designers, most of the data listed comes from American male and female, military and civilian studies. Other sources of data are surveys of British military males, and civilian males and females, as well as a study of Swedish civilians.

Applications of the data to seat design are suggested.

25. Barter, James T., and Milton Alexander. A Sizing System for High Altitude Gloves.

WADC TR 56-599, Wright Air Development Center, Wright Patterson Air Force Base, O., 21 pages, 3 references, 1956. (AD 110 589)

This report presents the rationale for and procedures followed in the development of a sizing program for high altitude gloves. This program is based on four divisions of hand circumference, each subdivided into three divisions of hand length, making a total of 12 sizes. A selected sample of 100 hands of male Air Force personnel and civilian personnel employed by the Air Force was measured to provide the 31 dimensions presented for design purposes. Summary statistics, regression equations, design dimensions, and a procurement tariff are presented in various tables throughout the report.

The results of a fit-test of two differing styles of gloves sized according to this program indicate that a high percentage of personnel can be fitted adequately in their indicated size. Detailed instructions for determining the indicated size of gloves are also included.

26. Barter, James T. Estimation of the Mass of Body Segments.

WADC TR 57-260, Wright Air Development Center, Wright Patterson Air Force Base, O., 10 pages, 5 references, 1957. (AD 118 222)

The present study is concerned with the re-analysis of data on the mass of body segments published in Space Requirements of the Seated Operator, Dempster, WADC TR 55-159, 1955, and in The Center of Gravity of the Human Body as Related to the Equipment of the German Infantry, Braune and Fischer, 1889. This report attempts to treat statistically the combined samples of Dempster and Braune and Fischer (12 cadavers) and to present the resulting information in a way that will be of maximum utility to designers. Regression equations for computing the mass of body segments for any known body weight are presented along with data on estimated weights of body segments of Air Force flying personnel.

27. Barter, James T., Irvin Emanuel and Bruce Truett. A Statistical Evaluation of Joint Range Data.

WADC TN 57-311, Wright Air Development Center, Wright Patterson Air Force Base, O., 22 pages, 34 references, 1957. (AD 131 028)

Joint mobility data published by Dempster in 1955 (Space Requirements of the Seated Operator, WADC TR 55-159) have been re-analyzed and presented in a form intended to be more applicable to Air Force design problems. The sample consisted of 39 male students on whom 43 body joint movements were studied. As originally presented by Dempster, the data was divided according to four subgroups categorized by somatotype. In this report the subgroup statistics were combined to yield summary statistics arranged into more convenient tabulations for the designer. Design values showing the range of each of the 43 joint movements are given, with other summary statistics, to serve as a guide to movement capabilities in crewstation design, particularly in the location of controls.

28. Beatty, H. T. and T. E. Berghage. Diver Anthropometrics.

Report #10-72, Navy Experimental Diving Unit, Washington Navy Yard, Washington, D. C. 20390, 156 pages, 1972.

Fifty-four anthropometric measures, two pulmonary function measures and three derived body measures were obtained from 100 U.S. Navy divers. Descriptive statistics and measures of interrelationship are given for each measured and derived variable.

A comparison with anthropometric data available for male aviation populations indicated that the U.S. Navy diving population is significantly different from the general aviation population (heavier, shorter, smaller-chested, etc.). Authors conclude that the use of the more widely available aviation anthropometric data in the design of diving equipment and systems would lead to inappropriate design specifications.

29. Behan, R. A. and H. W. Wendhausen. Some NASA Contributions to Human Factors Engineering: A Survey.

NASA SP-5117, National Aeronautics and Space Administration, Washington, D.C., 103 pages, 15 references, 1973.

The major portions of this book describe various devices and techniques developed under the auspices of NASA for use in measuring and estimating human responses under zero-gravity conditions. These include development of a mathematical model of man for use in simulation studies of performance at zero-gravity, techniques that can be used to study the effects of vibration on human performance, and techniques for studying the physiological effects of weightlessness on the human body. Of particular relevance to engineers concerned with the design of controls requiring exertions of force is a chapter which contains tabular data on strength capabilities under various conditions of restraint necessary in the zero-gravity environment. Hand, waist and shoe restraints as well as varying combinations were tested and results given.

30. Bolton, C. B., M. Kenward, R. E. Simpson and G. M. Turner. An Anthropometric Survey of 2,000 Royal Air Force Aircrew 1970/71.

TR 73083, Royal Aircraft Establishment, Farnborough, Hants, England, 138 pages, 1973.

Sixty-three body measurements of each of 2,000 RAF aircrew between the ages of 18 and 45 were made and the results summarized in the form of percentile tables and summary statistics. Photos illustrating the measurement techniques and instruments accompanying the text.

The survey was undertaken to provide up-to-date information on body dimensions of RAF aircrew for purposes of designing cockpits and developing sizing programs for military clothing.

31. Booth, R. A. D., B. A. Goddard and A. Paton. "Measurements of Fat Thickness in Man: A Comparison of Ultrasound, Harpenden Calipers and Electrical Conductivity."

British Journal of Nutrition, 20:719-725, 6 references, 1966.

Subcutaneous fat thickness was measured by three different techniques in 41 subjects--26 men and 15 women ranging in age from 16 to 87 years. Ultrasound provided the most accurate measurement in experienced hands. A method based on electrical conductivity was also accurate but was unpleasant for the subject. Harpenden calipers were the least satisfactory of the three techniques tested.

32. Braune, W. and O. Fischer. Bestimmung der Tragheitsmomente des Menschlichen Körpers und Seiner Glieder (in German).

S. Hirzel, Leipzig, Germany, 87 pages, 1892.

The authors measured the segment mass, length, and two moments of inertia on two German cadavers. The moments of inertia were measured about a transverse axis and a longitudinal axis. The data are reported for each cadaver.

33. Braune, W. and O. Fischer. The Center of Gravity of the Human Body as Related to the Equipment of the German Infantry.

S. Hirzel, Leipzig, Germany, 129 pages, 1889.

The authors measured the whole body center of gravity on four German, adult male cadavers and the same data were measured on body segments from two of the same cadavers. The whole body center of gravity for these cadavers lay within the pelvis, near the sacral promontory, for the standing position. The segments were separated at the approximate center of joint rotation and the subsequent center of gravity data were all reported relative to the segment proximal joint. Segment weights were also reported. In addition, the authors studied the shift in center of gravity with position and load in a living male model representative of a German infantry man. These data were measured from photographs and assumptions regarding the applicability of the cadaver weight and c.g. data to a living man. The results are reported in coordinates as well as anatomical description.

This is the classic work which introduces mass distribution studies.

34. Brown, Jeri W. Zero-g Effects on Crewman Height.

JSC Internal Note 76-EW-3, National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, Tex., 12 pages, 7 references, 1976.

This report documents the changes in stature which take place in space flight as recorded in the Skylab 4 and Apollo-Soyuz Test Project (ASTP) missions. Pre-flight, in-flight and post-flight data are given. Results show that crewmen gained about two inches of height in zero-gravity. Data from measurements taken on the ASTP crew show a two-phase growth: only a small change (averaging .5 inch) took place between launch and mission day six while the balance of the two-inch "growth" took place between mission day six and mission day nine. Skylab measurements did not begin until mission day 21.

35. Brown, John R. Manual Lifting and Related Fields: An Annotated Bibliography.

Labour Safety Council of Ontario, 400 University Avenue, Ontario, Canada, 583 pages, 1972.

Emphasis in this annotated collection is on the causes and prevention of low back pain and other back injuries resulting from lifting tasks. Although the book is largely concerned with physiology, it contains considerable data of direct interest to design engineers on the incidence of back injury broken down by age and sex; recommended techniques for lifting; the effects of posture on lifting and carrying; and some material on recommended loads in terms of both weight and placement.

36. Bullock, Margaret I. "The Determination of Functional Arm Reach Boundaries for Operation of Manual Controls."

Ergonomics, 17:3, 375-388, 23 references, 1974.

Subjects in this study of functional arm reach were 75 men and 35 women selected to represent exactly the height distribution of male and female Australian pilots. They were firmly harnessed into a simulated light aircraft seat and maximum arm reach to 170 positions in space around each subject was measured. Results are presented in a table showing boundaries reached by 95% of male and 95% of female pilots for each position.

The authors suggest that the method of measuring functional arm reach which they describe in this paper proved to be an accurate and rapid means of data collection and recommend its use for determination of space envelopes relevant to the accommodation and work area conditions of other vehicles and cockpits.

37. Caldwell, Lee S., et al. "A Proposed Standard Procedure for Static Muscle Strength Testing."

American Industrial Hygiene Association Journal, 35(4):201-206, 20 references, 1974.

The authors are concerned about the lack of agreement in terminology and definitions, methods of assessment, statistical treatment of data, etc., in static muscular strength testing. A recommended definition of "static strength" is the capacity to produce torque or force by a maximal voluntary isometric muscular exertion. Recommendations are given pertaining to the strength exertion, strength score, test purpose and procedures, instructions to the subject, strength testing conditions, subject description and data reporting. The authors conclude that explicit instructions to subjects in strength studies are necessary and emphasize the importance of reporting in detail all factors which influence the generation of force and its application to a transducer.

38. Cathcart, E. P., D. E. R. Hughes and J. G. Chalmers. The Physique of Man in Industry.

Medical Research Council, Industrial Health Research Board Report No. 71, His Majesty's Stationery Office, London, England, 43 pages, 17 references, 1935.

This report contains information about selected measurements of 13,656 individuals, aged 14 years and up, sampled from the various occupational subdivisions listed in the 1921 Census of England and Wales; the sample included 1,328 unemployed men and 1,735 students. Height, weight, left and right-handed grip strength, lifting and pulling strengths, and floor-to-middle-finger-tip were measured.

Conclusions about changes occurring with advancing age and variations between various subgroups of the total sample are documented and discussed. Numerous tables present the data in full detail.

On the average, students were found to be superior in all measurements (taller, heavier, stronger) to both the employed and unemployed groups. Based on the employed group, maximum height occurs at 20-21 years. Grip increases to about 20 years of age and is held uniform till about 40, when a slow decline sets in. Pulling strength was shown to increase up to 25 1/2 - 27 1/2 years of age with a decline beginning at age 30.

39. Chaffee, J. W. Andrometry: A Practical Application of Coordinate Anthropometry in Human Engineering.

Report FZY-012, Convair Division of General Dynamics Corporation, Fort Worth, Tex., 146 pages, 39 references, 1961. (AD 256 344)

This report presents in detail the theory and application of a photographic technique for obtaining three-dimensional coordinates of bodily features (andrometry) for purposes of accurately determining the size and location of the human operator's anatomy in three-dimensional space. Also included is a description of the construction and an andrometric facility, results of validation tests, and specific examples of design problems to which andrometry has been successfully applied. The latter include design of an escape capsule and determining the location of the pilot's eyes when flying encapsulated.

40. Chaffin, Don B. Graphical Predictions of Human Strengths for Two-Handed IV/EVA's: Phase One Report.

NASA/MSC Contract No. NAS9-10973, National Aeronautics and Space Administration, Biomedical Division, 171 pages, 24 references, 1971.

This paper is largely devoted to graphical displays of predicted two-handed strength capabilities, both shirt sleeved and space suited, as they are affected by (1) vertical and horizontal hand positions in front of or above the ankles, (2) gravity conditions (1.0, 0.7 and 0.2 g's), and (3) population size and strength (5th, 50th and 95th percentiles). Pushing, pulling and lifting tasks are measured and conclusions of use to designers of systems and equipment are presented in detailed and general summaries of the significant factors which affect the various tasks under varying conditions.

All strength predictions are based on simulations performed with a computerized biomechanical model for which further more comprehensive uses are suggested.

41. Chaffin, Don B. Human Strength Simulations for One- and Two-Handed Tasks in Zero Gravity: Phase Two Report.

NASA/MSC Contract No. NAS9-109730, National Aeronautics and Space Administration, Biomedical Division, 145 pages, 164 references, 1972.

This paper describes the use of computerized three-dimensional strength simulations and reports on a particular model capable of predicting the hand forces that could be expected of an anthropometrically defined proportion of the population when performing under given conditions.

The results of two such simulations are given. One demonstrates the effects of various body configurations, hand positions and human anthropometry on human strengths in six specific operations tasks aboard the Skylab. Specific design recommendations result. The second set of simulations, whose object is to assist in the general design of workplaces, presents, in tabular form, one-handed force predictions for various control placements and directional movements for the seated operator at zero gravity.

42. Chaffin, Don B. "Human Strength Capability and Low Back Pain."

Journal of Occupational Medicine, 16(4):248-254, 26 references, 1974.

Isometric lifting strength tests were performed on some 500 male and female industrial workers to determine maximum lifting strength. Noteworthy results relevant to the subject at hand included the following: (1) women demonstrated a mean strength of about 58% of the men, lower than previously reported European studies, and (2) variations in the population values in this study were very wide, at least double those reported in an earlier study.

In view of the above findings, the author emphasizes the need for individual testing to properly fit the worker with a workload which is within his or her capacity to perform.

43. Champion, M. C. and W. G. A. Port. Head and Neck Mobility of Pilots Measured at the Eye.

TR 74158, Royal Aircraft Establishment, Farnborough, Hants, England, 21 pages, 4 references, 1974.

Head and neck mobility of nine pilot subjects was studied by measuring the movement envelope of the pilot's eye position as he craned his head and neck up, down, and from side to side. The subjects were strapped into an ejection seat instrumented to monitor harness tension and instructed to look forward at a target board through a sight aperture. Tests were made with subjects clothed in winter and summer RAF aircrew equipment assemblies and with and without helmets; differences in movement were assessed.

Results, presented graphically and tabularly, detail the limits of the eye envelope both with maximum movement of the head and neck and with "comfortable" ranges of movement; the latter are about 2/3 or 3/4 of the former. Data on seat harness tension is also presented.

Purpose of the study was to aid designers in determining the ranges of extreme and comfortable head movement that can be achieved by pilots to look around obstacles and through fixed head-up displays.

44. Chandler, R. F., C. E. Clauser, J. T. McConville, H. M. Reynolds and J. W. Young. Investigation of Inertial Properties of the Human Body.

AMRL TR 74-137, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 170 pages, 62 references, 1975. (AD A0 16485)

This report supplements existing information on the size, weight and center of mass of the body and its segments with new data on the mass distribution characteristics of the human body as described by the principal moments of inertia and their orientation to body and segment anthropometry. The weight, center of mass location and principal moments of inertia of six cadavers were measured. The cadavers were then segmented and the mass, center of mass, moments of inertia and volume were measured on the fourteen segments from each body. Standard and three-dimensional anthropometry of the body and segments were also determined.

The mathematical rationale and the techniques of measurements are described in detail. Results of the investigation are given as individual data values as well as summary statistics.

Data from this investigation is aimed at improving biological input for biomechanical modelling.

This is the only source for principal moments of inertia of the human body and body segments.

45. Churchill, Edmund. "Statistical Considerations."

Chapter Three in Human Development, ed. F. T. Faulkner, pp. 40-75, W. B. Saunders, Philadelphia, Pa., 1966.

Purpose of this chapter is to provide acquaintance with the language and basic techniques of statistics for researchers and engineers concerned with interpreting and critically evaluating data on human development. Attention is given equally to explaining the statistics used to describe and summarize sets of data and those used to infer from a sample the statistical properties of the population from which the sample is drawn.

Included are sections covering frequency distributions, percentiles, correlation coefficients, regression equations, standard errors and confidence limits, tests of significance, multivariate statistics, statistical vs. practical significance, and the interpretation of experimental statistics.

46. Churchill, Edmund and Katherine Bernhardt. WAF Trainee Body Dimensions: A Correlation Matrix.

WADC TR 57-197, Wright Air Development Center, Wright Patterson Air Force Base, O., 75 pages, 7 references, 1957. (AD 118 161)

Correlation coefficients expressing the degree of relationship between the 1830 pairings of 61 WAF basic trainee body dimensions are presented in this report. Slightly over 2,000 multiple correlation coefficients expressing the degree of relationship between each of these dimensions and 36 pairs, selected for their potential usefulness, are also given. Regression equations for estimating all other dimensions from the most frequently occurring values of stature, weight and stature-weight combinations are listed. This correlation material supplements the basic dimensional data given in Anthropometry of WAF Basic Trainees, WADC TR 53-12 and, with that data, provides a basis for the planning and execution of design programs involving the body dimensions of these individuals.

47. Churchill, Edmund and Gilbert S. Daniels. Nomographs of Head Measurements.

WADC TR 53-14, Wright Air Development Center, Wright Patterson Air Force Base, O., 26 pages, 5 references, 1953. (AD 16748)

To achieve the optimum design of equipment intended to fit the wearer's head closely, a knowledge of the interrelationships between the more important head dimensions is necessary. This report provides such information in the form of two nomographs for determining the most accurate estimate for each of twelve head dimensions based on known values of head length and head breadth, and head breadth and head circumference.

Head measurements used in these nomographs were obtained from the 1950 survey of 4,063 Air Force flying personnel.

48. Churchill, Edmund, Alma Kuby and G. S. Daniels. Nomograph of the Hand and Its Related Dimensions.

WADC TR 57-198, Wright Air Development Center, Wright Patterson Air Force Base, O., 49 pages, 9 references, 1957. (AD 118 162)

Dimensional data for the hands of both male and female USAF personnel are summarized in tabular and graphic form. Values for the various inter-correlations are given in tables of correlation coefficients. A further series of tables supplies estimates of the other dimensions for instances in which the specified dimension is hand length, hand breadth at metacarpale, hand breadth at thumb or fist circumference. Similar estimates, in the form of nomographic charts, are provided for those instances in which both length and breadth are specified.

The basic data used in this study were obtained from the 1950 USAF survey of 4,063 male flying personnel and the 1953 survey of 852 WAF basic trainees. Data obtained from other surveys of military personnel are summarized and suggest that the tables and charts presented here are applicable to the design of articles intended for almost any group of USAF personnel.

49. Churchill, Edmund and John T. McConville. Sampling and Data Gathering Strategies for Future USAF Anthropometry.

AMRL-TR-74-102, Aerospace Medical Research Laboratory, Wright Patterson Air Force Base, O., 133 pages, 51 references, 1976.

Beginning with a comprehensive review of anthropometric resources already available, this report serves as a guide to more refined and less costly methods of acquiring needed anthropometric data to meet changing requirements and to accommodate changing populations. Many sampling schemes are described and evaluated for their utility in meeting specific needs. Various measurement and sampling errors are discussed and the effects of each type of error on the statistics of major importance in design problems are explained.

A recommended plan for the future acquisition of anthropometric data incorporates specific steps designed to: (1) update basic population data, (2) follow and project secular trends, and (3) devise surveys tailored to obtain specific task-oriented information.

50. Churchill, Edmund, John T. McConville, Lloyd L. Laubach, and Robert M. White. Anthropometry of U.S. Army Aviators 1970.

TR 72-52-CE, Clothing and Personal Life Support Equipment Laboratory, U.S. Army Natick Laboratories, Natick, Mass., 335 pages, 1971.

This report describes an anthropometric survey of U.S. Army aviators conducted in 1970. Data for the 85 measurements and for several variables describing the sociomilitary background of the survey population were gathered on a sample of 1,482 flying personnel. Statistical summaries are presented for each measurement for the entire sample and for five subseries. Summary statistics and percentiles for 80 anthropometric indices and for some 73 anthropometric variables computed from the measured dimensions are given, as is the correlation matrix for the measured variables and age.

51. Churchill, Edmund and Bruce Truett. Metrical Relations Among Dimensions of the Head and Face.

WADC TR 56-621, Wright Air Development Center, Wright Patterson Air Force Base, O., 127 pages, 11 references, 1957. (AD 110 629)

This report is designed to contribute to the storehouse of basic data for use in designing masks, helmets and other special devices which must fit the head and face when more than a single dimension is simultaneously involved in a design problem.

Based on data from the 1950 Anthropometric Survey of USAF Flying Personnel, in which 41 measurements of the face and head of 4,063 subjects are reported, this study consists chiefly of the more than 800 correlation coefficients which specify the degree and direction of the relationship existing between each pair of the 41 dimensions. Also presented here are (1) regression equations for those pairs of dimensions which are at least moderately related to each other, (2) bivariate frequency tables for many of these same pairs of dimensions for use in planning a sizing program and establishing tariffs, (3) selected multiple correlation coefficients measuring the relationship between one dimension and a combination of two others.

A small amount of similar data, based on a sample of 852 WAF basic trainees, is also given.

52. Clarke, H. Harrison. Muscular Strength and Endurance in Man.

Prentice-Hall, Inc., Englewood Cliffs, N. J., 211 pages, 90 references, 1966.

Numerous studies of strength and endurance are described in this monograph; instrumentation, methods and results are presented and discussed. Areas covered include: (1) strength testing with emphasis on cable-tension tests, (2) endurance studies, (3) investigations of the strength decrement manifestations of muscle fatigue and establishment of a Strength Decrement Index, (4) applications of the Strength Decrement Index and (5) various muscular strength and muscular fatigue relationships including: intercorrelations of strength tests; correlations of strength tests with physical-motor measures, athletic ability and maturity; muscular fatigue relationships; and muscular strength-endurance relationships. A final chapter assembles conclusions that may be drawn from the results of the studies presented in this book.

This book should be in the hands of everyone involved in the broad area of biomechanics. It is an excellent reference source.

53. Clauser, Charles E., et al. Anthropometry of Air Force Women.

AMRL-TR-70-5, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 1,157 pages, 30 references, 1972. (AD 743 113)

This report describes and summarizes the results of an anthropometric survey of U.S. Air Force women, carried out in 1968. A total of 137 dimensions were measured on a sample of 1,905 subjects--548 officers or officer trainees and 1,357 enlisted. The final list of measurements included 5 measures of weight and body composition, 30 of body height and length, 26 of body girth, 15 of body breadth and depth, and 12 of body surface distance. Also, there were 30 measures of the head and face, 3 of the hand, 2 of the feet, 1 of grip strength and 13 remeasures of the subject wearing a foundation garment of her choice. A study of the body density of a subsample of 95 subjects is also included.

Other features of this report are a variety of correlation and regression equation material, including the complete correlation matrix for the basic 124 measurements, regression equations for all pairs of variables with at least moderately high intercorrelations, selected partial and multiple correlations, and a series of stepwise regression equations, as well as 400 bivariate frequency tables and one trivariate table.

54. Clauser, Charles E., John T. McConville and J. W. Young. Weight, Volume, and Center of Mass of Segments of the Human Body.

AMRL-TR-69-70, Aero Medical Research Laboratory, Wright Patterson Air Force Base, O., 101 pages, 95 references, 1969. (AD 710 622)

This study was designed to supplement existing knowledge of the weight, volume and center of mass of segments of the human body and to ascertain whether these values can be predicted in living persons from standard anthropometric measures. Weight, volume and center of mass of 14 segments of the body were determined from 13 male cadavers and predictive equations developed. Data developed in this investigation indicate that the anthropometry of the body can be used effectively to predict weight and location of the center of mass of body segments both for individuals and for populations, though the authors caution that these predictive equations should not be regarded as more than good first approximations until adequately validated on live populations.

55. Cleaveland, Henry G. The Determination of the Center of Gravity of Segments of the Human Body.

Dissertation, University of California, Los Angeles, Ca., 91 pages, 45 references, 1955.

The author measured the location of the center of gravity for the head and neck, trunk, arm, forearm, hand, thigh, leg and foot. The segment center of gravity was assumed to lie in a plane which divided the segment into two equal volumes. Measurements were made on 11 white male subjects for length of body segments, height, weight, and segment volume.

56. Coblentz, A. and G. Ignazi. Etude Cephalometrique de Jeunes Francais (in French).

Anthropologie Applique, 45 Rue des Saints-Peres, Paris-6, France, 2 Volumes: Vol. I, 160 pages, 60 references; Vol. II, 111 pages, 1968.

Sixty-seven head and face measurements were made in this study of 2,000 young Frenchmen averaging 18 years of age. A large portion of the first volume is taken up with illustrations of the measurements taken and tables showing summary statistics of the results. Comparisons are made between the 1,500 subjects selected from the Paris area and groups of 100 subjects each from five provinces of France.

The balance of the first volume and all of the second volume contain statistical comparison of selected measurements in which subjects are re-grouped by profession, place of birth, number of siblings, etc. Also graphed and tabulated are comparisons of the subject data with the results of similar studies of French military subjects and non-French populations.

Since the data presented in these volumes is largely graphic and numerical, only a rudimentary knowledge of French terms is required to comprehend the material.

57. Corlett, E. N. and R. P. Bishop. "Foot Pedal Forces for Seat Operators."

Ergonomics, 18(6):687-692, 8 references, 1975.

Ten male and ten female subjects representative of a civilian industrial population were tested to determine the maximum isometric force that a seated operator could exert on a horizontal foot pedal. The pedal was located at four different experimental positions.

Results showed no significant differences between right and left legs. Male leg strengths were 9-50% greater than female leg strengths depending on the position of the foot pedal. For both male and female subjects, the highest force was exerted when the pedal was located at a vertical distance from the seat midway between maximum and minimum reachability as determined by popliteal (floor to inside of knee) distances and acceptable ranges of hip and knee joint movements of 5th percentile operators.

58. Covault, Craig. "Skylab Provides Habitability Guidelines."

Aviation Week & Space Technology, 100:58-61, 1974.

This brief article describes some subjective impressions and observations of nine astronauts who participated in three Skylab missions. Comments on various aspects of living in zero-g cover up-down orientation, the tendency to widely miss the mark when reaching for things in the dark, doors vs. hatches, restraints and mobility, maintenance, and a variety of house-keeping problems unique to the zero-g environment.

Many of the comments suggest modified approaches to workspace design.

59. Damon, Albert, Howard W. Stoudt and Ross A. McFarland. "Anthropometry."

Chapter 11 in Human Engineering Guide to Equipment Design, Morgan, Clifford T., et al., eds., McGraw-Hill Book Co., Inc., New York, N.Y., 130 pages, 1963.

This chapter contains extensive anthropometric, muscle-strength, and range-of-motion data on numerous United States military populations. Many individual dimensions and their measurements are described, illustrated, and tabulated. Specific figures which will accommodate given percentiles of a population are cited and followed by specific values by which the original figure should be altered to accommodate different sexes, varying conditions of clothing or protective gear, or members of different military services.

Introductory material outlines the basic concepts and the many applications of the data described above to many types of human engineering problems.

This paper is an unusually clear, comprehensive and useful presentation of basic information needed by designers of clothing, equipment and workspaces.

60. Damon, Albert and Ross A. McFarland. "The Physique of Bus and Truck Drivers with a Review of Occupational Anthropology."

American Journal of Physical Anthropology, 13(4):711-742, 99 references , 1955.

Beginning with a review of the literature of occupational anthropology which showed some consistent occupational differences in physique often, but not always, related to the exertion required, the authors describe a study of 375 bus and truck drivers. Some 33 anthropometric measurements, chosen for utility in vehicle design, were made. In addition, somatotypes were established and limited grip strength testing was undertaken.

Results showed that drivers of heavy vehicles were about as tall as the average American but were somewhat heavier and stockier and had somewhat larger chests. They were decidedly more mesomorphic and less gynandromorphic (more "masculine").

61. Daniels, Gilbert S. The "Average Man"?

TN WCRD 53-7, Wright Air Development Center, Wright Patterson Air Force Base, O., 7 pages, 2 references, 1952. (AD 102 03)

This technical note clearly demonstrates the fallacy of the "average man" concept for design problems involving body dimensions, particularly in the design of clothing, equipment or work spaces involving more than one body dimension.

Data used to substantiate the thesis that the average man is, in fact, so rare as to be non-existent in real life were based on material from the 1950 Air Force Anthropometric Survey in which 131 measurements were obtained from over 4,000 flying personnel. Selecting 10 measurements useful for clothing design, the author statistically examined the 4,063-man sample with a view toward determining the number of men in the "approximately average" category. Only a tiny fraction of the subjects were found to fall into this category with respect to five of the 10 measurements; progressive culling for the remaining five measurements reduced this number to zero.

It is suggested that data on the range of variability in human dimensions is available and is more suitable for use by design engineers.

62. Daniels, Gilbert S., H. C. Meyers, Jr., and Edmund Churchill. Anthropometry of Male Basic Trainees.

WADC TR 53-49, Wright Air Development Center, Wright Patterson Air Force Base, O., 99 pages, 4 references, 1953. (AD 207 17)

Body size data for 60 measurements of over 3,000 Air Force male basic trainees are presented for use by aircraft and equipment designers.

The statistics reported for each measurement are: the mean, standard deviation, coefficient of variation, standard errors of these statistics, range, and selected percentiles from the first to the 99th. The statistics are reported in both the metric and English values.

A complete description of the anthropometric techniques used is presented.

63. Daniels, Gilbert S., H. C. Meyers, Jr., and Sheryl H. Worrall. Anthropometry of WAF Basic Trainees.

WADC TR 53-12, Wright Air Development Center, Wright Patterson Air Force Base, O., 103 pages, 4 references, 1953. (AD 205 42)

Body size data for 63 dimensions of 852 Women's Air Force basic trainees are presented for use by the designers of Air Force equipment.

The statistics reported for each measurement include the mean, standard deviation, coefficient of variation, standard errors of these statistics, range and selected percentiles from the first to the 99th. These statistics are reported in both the metric and the English values.

A complete description of the anthropometric techniques used is presented.

64. Davenport, Charles B. and A. G. Love. Army Anthropology.

Government Printing Office, Washington, D.C., 20402, 635 pages, 1921.

This is a detailed account of an anthropometric study of 100,000 World War I military men at demobilization. Some 21 dimensions were measured and are discussed at length. Data for each dimension is compared with data obtained for Civil War soldiers and correlated with other dimensions. The figures are also broken down by ethnic origin and by U.S. state and/or geographical region and frequency distributions calculated.

65. Dempster, Wilfrid T., W. Creighton Gabel and William J. L. Felts.
"The Anthropometry of the Manual Work Space for the Seated Subject."

American Journal of Physical Anthropology, 17(4):289-317, 47 references, 1959.

The anthropometry of the manual work area for seated subjects was approached by using photo records of time exposures showing the motions of a tiny neon lamp as the hand grip. The records of 22 male college students were analyzed for three sets of motions involving the forward-directed hand in different grip orientations. Graphic records of the different hand-range spaces were grouped and compared to ascertain variability data, the extent of right-left hand overlap, regions of maximum hand flexibility, mean hand positions, etc.

The data are discussed in terms of the more effective hand positions and in terms of practical problems of work space design.

This article is particularly lucid since it includes a number of clear explanations of the terms and concepts employed in this sort of study.

66. Dempster, Wilfrid T., Lawrence A. Sherr and Judith G. Priest. "Conversion Scales for Estimating Humeral and Femoral Lengths and the Lengths of Functional Segments in the Limbs of American Caucasoid Males."

Human Biology, 36(3):246-262, 16 references, 1964.

This paper reports the results of a study defining link lengths of the upper arm, forearm, thigh and calf from anthropometric measurements of living subjects. Tables of coefficients, regression equations and nomograms for estimating link length from bone length and anthropometric segment length are presented. The tables on bone length are based on data from 545 white male skeletons studied by Dr. M. Trotter; the tables on link lengths are based on data from the right and left limbs of 30 embalmed white male cadavers.

This is a necessary reference for dealing with limb links although limited to white male populations.

67. Dempster, Wilfred T. Space Requirements of the Seated Operator: Geometrical, Kinematic, and Mechanical Aspects of the Body with Special Reference to the Limbs.

WADC TR 55-159, Wright Air Development Center, Wright Patterson Air Force Base, O., 254 pages, 172 references, 1955. (AD 878 92)

This report describes work on certain anatomical, geometrical and mechanical features of the male body which are essential for (1) the design of two- and three-dimensional manikins capable of realistic movements, (2) understanding the body kinematics of a seated operator in his work space, and (3) defining work space dimensions. Attention in this study has been largely limited to the range and position of hands and feet, to joints of the limb system, and to the space envelope needed to encompass their movements.

Thirty-nine male students, divided into four somatotyped groups, were used to provide information on the range of possible hand and foot movements consistent with the seated posture. Maximum dimensions of the workspace for seated individuals were determined and a study of the kinematic factors involved yielded an evaluation of the potential utility of different regions within reach.

Eight cadavers were dismembered to provide data on such physical constants as mass of parts, segment centers of gravity, density, and movements of inertia. Also described in this report is research undertaken to determine the distribution of body bulk and an analysis of horizontal push and pull forces to determine the effectiveness of body mass, leverages and support areas.

This is a basic reference for mass distribution of the human body.

68. Dobbins, D. A. and C. M. Kindick. Anthropometry of the Latin-American Armed Forces.

Report No. 7209002, U.S. Army Tropic Test Center, Fort Clayton, Canal Zone, 60 pages, 15 references, 1972.

Anthropometric measurements were taken on 1,985 Latin American Army and Air Force trainees attending the U.S. Army School of the Americas. Fifteen countries were represented.

Average age for the sample was 23 years, average height was 5 feet, 5 and one-half inches, and average weight was 141 pounds.

Percentiles and ranges for 75 measurements are presented. These include measurements of isometric strength and hand-grip. Also given are country-by-country comparisons and comparisons of the Latin American data with comparable Thai and USAF data.

69. Donnelly, Richard J. A Study of the Dynamometer Strength of Adult Males Ages 30 to 79.

Microfilmed doctoral dissertation, University of Michigan, Ann Arbor, Michigan, 1953.

The problem of this dissertation was to investigate the dynamometer strength of adult males 30 years of age and older. A total of 534 adult males between the ages of 30 to 79 were tested for static strength of the right and left grip, arm pull, arm push, back lift, and leg lift. The subjects were primarily either from the Detroit, Michigan YMCA's or inmates of Southern Michigan prison. Average strength was computed for eight age brackets on the basis of five-year spans to age 51 and of ten-year spans from 60-79. Percentile tables were made for ten-year age brackets for the different strength tasks.

The evidence shows that an adult attains maximum dynamometer strength in his thirties. The marked decline in dynamometer strength commences between the ages of 37 and 42.

This is one of the most comprehensive studies on muscle strength measurements that has been completed on a sample other than a college-age population.

70. Drillis, Rudolf and Renato Concini. Body Segment Parameters.

Report # 116.03, New York University School of Engineers and Science, New York, N.Y., 109 pages, 62 references, 1966.

This report provides results of measurements of segment weight, center of gravity, and mass moments of inertia. Data are based on volumetric measurements of the body segments (head-neck-torso, upper arm, forearm, hand, thigh, calf and foot). The authors critically examine various techniques and conclude that theirs provide suitable results for determining body segment parameters useful in orthotics and prosthetics, dummy design, and terrestrial and interplanetary transportation problems.

71. DuBois, J., W. R. Santschi, D. M. Walton, C. O. Scott and F. W. Mazy. Moments of Inertia and Centers of Gravity of the Living Human Body Encumbered by a Full-Pressure Suit.

AMRL-TR-64-110, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 54 pages, 7 references, 1964. (AD 609 863)

The center of gravity and the moments of inertia of each of 19 male subjects, representative in stature and weight of the U.S. Air Force population, were determined. Two body positions: sitting and relaxed (simulating weightlessness), and three modes of dress: nude, suited-unpressurized, and suited-pressurized, were investigated. The moments of inertia were found to vary significantly between body positions and between nude and suited conditions. Correlation coefficients between moments of inertia and stature and weight were high while standard errors were low, indicating that moments of inertia of the suited as well as the nude individual can be computed from data on the subject's stature and nude weight. Fifty anthropometric dimensions and frontal and profile photographs were also obtained on each subject.

Data in this study are useful in the design of restraint, escape and propulsion systems.

72. Dzendolet, Ernest and John F. Rievley. Man's Ability to Apply Certain Torques While Weightless.

WADC TR 59-94, Wright Air Development Center, Wright Patterson Air Force Base, O., 28 pages, 8 references, 1959. (AD 220 363)

The torque that a maintenance man can exert within a space vehicle while weightless, and hence tractionless, is analyzed. Anthropological literature was reviewed to determine the torques a man can apply under normal conditions. Using elementary physical principles, the consequences of applying these torques while tractionless were calculated. Certain of the predictions were verified experimentally on five or six subjects. It was tentatively concluded that standard anthropometric data can legitimately be extrapolated to the weightless condition.

Suggestions are advanced regarding (1) the optimum body position for simple tightening tasks without using a handhold, (2) the use and location of handholds, (3) maximum torque limitations, (4) the use of impulses, and (5) the design of hand tools.

73. Emanuel, Irvin, Milton Alexander and Edmund Churchill. Anthropometric Sizing and Fit-Test of the MC-1 Oral-Nasal Oxygen Mask.

WADC TR 58-505, Wright Air Development Center, Wright Patterson Air Force Base, O., 23 pages, 6 references, 1959. (AD 213 604)

A sizing program for oral-nasal oxygen masks, based on total face length and lip length, has been developed through a re-analysis of the 1950 USAF Anthropometric Survey head and face data (4,063 subjects). Face forms based on this sizing program have been constructed for use in the preparation of such masks, and development of the MC-1 Oxygen Mask in accordance with these face forms is described. In the fit-tests, 149 or 150 subjects were satisfactorily fitted in their indicated sizes.

This report includes a discussion of the theoretical and practical aspects of the sizing procedure. Design limits, related statistical material, and suggested procurement tariffs for each of the six proposed sizes are given.

74. Emanuel, Irvin and Milton Alexander. Height-Weight Sizing and Fit-Test of a Cutaway G-Suit, Type CSU-3/P.

WADC TR 57-432. Wright Air Development Center, Wright Patterson Air Force Base, O., 22 pages, 5 references, 1957. (AD 130 912)

Body size data from the 1950 Air Force Flying Personnel Survey have been re-analyzed to yield a statistical sizing program based on height and weight. This six-size program was incorporated into the Type CSU-3/P Cutaway Anti-G Garment which was tested from the standpoint of fit and comfort. Suit selection was accomplished simply by asking each subject his height and weight. Of 73 subjects fitted, 72 were comfortably accommodated by the size indicated by height and weight values. (Forty-three Aero Medical Laboratory personnel and 30 USAF aircrew served as subjects). It is concluded that this sizing procedure will result in the saving of time and money because of the ease of fitting, reduction of individualized tailoring and simplification of procurement.

75. Emanuel, Irvin, Milton Alexander, Edmund Churchill and Bruce Truett. A Height-Weight Sizing System for Flight Clothing.

WADC TR 56-365, Wright Air Development Center, Wright Patterson Air Force Base, O., 109 pages, 18 references, 1959. (AD 130 917)

This report discusses both the statistical and practical aspects of sizing flight clothing and describes the development of several sizing programs based on two body dimensions--height and weight. The choice and application of the different sizing programs are discussed and the advantages of these programs in the design, fitting and procurement of flight clothing are presented. Tables include fitting charts, estimated procurement tariffs, design ranges and average values for size groups, for six-, eight-, nine-, and 12- size programs as well as bivariate tables for height and weight with size categories marked off for each program.

Observations and recommendations reported here are based on a re-analysis of the body size data of the 1950 Anthropometric Survey of Air Force flying personnel.

76. Emanuel, Irvin and James T. Barter. Linear Distance Changes over Body Joints.

WADC TR 56-364, Wright Air Development Center, Wright Patterson Air Force Base, O., 38 pages, 1957. (AD 118 003)

This report provides data on the linear distance changes over joints resulting from specifically defined changes in limb positions. Head and neck, shoulder, elbow, wrist, finger, trunk, hip, knee, and ankle joints were studied on a sample of 30 male subjects comparable in measurement to the sample used in the 1950 Air Force Flying Personnel Survey. Summary statistics and design values are presented for 49 linear distance changes measured over these joints. The data represent maximum figures for the amount of increase or decrease in linear dimensions resulting from body segment movements.

The information is designed for application to close-fitting altitude clothing and can serve also as a guide for determining easement factors for more commonplace types of clothing. Since the changes noted are mostly unrelated to body size, the suggested design values are applicable to the complete range of garment sizes.

77. Emanuel, Irvin, John W. Chaffee and John Wing. A Study of Human Weight Lifting Capabilities for Loading Ammunition into the F-86H Aircraft.

WADC TR 56-367, Wright Air Development Center, Wright Patterson Air Force Base, O., 12 pages, 3 references, 1956. (AD 972 06)

Under investigation in this study was the weight lifting ability of a sample of 19 young men, chiefly students selected for comparability in measurements to the 1950 Air Force Flying Personnel Survey sample. The lifting procedures were standardized and controlled to simulate the loading of ammunition into the F-86H aircraft. An ammunition case with varying amounts of weight was lifted to platforms ranging from one to seven feet above the floor.

All subjects could lift the case in the prescribed fashion up to and including five feet above the floor; only nine subjects could properly lift to six feet, and only one individual achieved the seven-foot platform. Suggested maximum weights required for actual lifting tasks are presented. Based on fifth percentile values, they are as follows: one foot - 142 pounds; two feet - 139 pounds; three feet - 77 pounds; four feet - 55 pounds; five feet - 36 pounds.

78. Freedman, Arthur, et al. Foot Dimensions of Soldiers.

Project No. T-13, S.G.O. No. 611, Armored Medical Research Laboratory, Fort Knox, Ky., 164 pages, 1946.

Data for 27 foot dimensions measured on 6,278 white soldiers and 1,281 black soldiers are presented and analyzed. Purpose of the study was to derive, if possible, a single last pattern from which to make Army shoes.

Results of the survey showed a wide diversity of measurement and analysis of the data yielded poor correlation between any two dimensions.

In general, it appeared that all length, breadth and girth measurements and the dorsal toe elevation of blacks tended to be larger than those of white subjects. Conversely, toe length and breadth, all height measurements of the ball and arch and the girth of the lower leg tended to be smaller for blacks than for whites. Differences between the right and left foot were noted but no pattern of differences was discernable. Over a large population, differences between the two feet appeared to cancel out.

79. Fry, Edward I. and Edmund Churchill. Bodily Dimensions of the Older Pilot.

WADC TR 56-459, Wright Air Development Center, Wright Patterson Air Force Base, O., 39 pages, 3 references, 1956. (AD 972 17)

A comparison of 132 body dimensions on selected groups of older and younger pilots is presented. A comparison of mean values of each dimension was made and, additionally, for 20 selected dimensions, a more intensive comparison was made for five percentile groups. When differences were found to exist an explanation was sought in terms of the physical process of aging and of the differing recruitment criteria by which men in these two groups were originally selected by the Air Force.

Most of the older-younger pilot differences are small and statistically non-significant, but a few are of great importance and should be taken into account in designing equipment.

80. Gaito, John and Edmund C. Gifford. "Components of Variance in Anthropometry."

Human Biology, 30:120-127, 4 references, 1958.

The primary purpose of this paper was to obtain estimates of the sources of variation of anthropometric measurements. Three trained anthropometrists measured 3 sets of fourteen subjects. The measurements included height, weight, sitting height, knee height, buttock-leg length, buttock-knee length, elbow-elbow breadth, bicepoid diameter, span, anterior arm reach, and maximum arm reach. The 42 male subjects ranged in age from 19 to 68 years. The measurements which are most reliable are height, weight, span, and sitting height; least reliable are buttock-leg length, maximum arm reach, and anterior arm reach. A suggested procedure to help overcome the unreliability of these measurements is to obtain more than one sample of each measurement with some time interval between measurements.

81. Garrett, John W. "The Adult Human Hand: Some Anthropometric and Biomechanical Considerations."

Human Factors, 13(2):117-131, 1971.

Recent studies of the anthropometry and biomechanical characteristics of hands are summarized and presented in illustrated tabular form. These include: (1) conventional anthropometry of male and female hands, (2) the anthropometry of the relaxed hand, (3) spatial requirements for and biomechanical capabilities of bare and pressure-gloved hands, and (4) the ability to retain grips on a variety of selected handles under high dynamic loads.

The data assembled in this article are aimed at providing a realistic foundation for the general design of dynamic manual systems and workspaces for the bare and gloved hand.

82. Garrett, John W. An Introduction to Relaxed Hand Anthropometry.

AMRL TR 67 217, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 5 pages, 1 reference, 1971. (AD 731 183)

Anthropometric data comparing the length of the relaxed hand with the flat, straightened hand are presented. Measurements were taken from a subject population of 71 Air Force flying personnel.

The data are of use in the design of hardware, as it has been found that the full pressure glove, for example, will enable the operator to work with greater efficiency and less fatigue if patterned to the naturally relaxed hand than a glove designed to the flat hand.

83. Garrett, John W. Anthropometry of the Air Force Female's Hand.

AMRL-TR-69-26, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 81 pages, 23 references, 1970. (AD 710 202)

This report contains descriptions of 56 anthropometric dimensions measured on hands of 211 Air Force female personnel (WAF, Nurse Corps and Biomedical Sciences Corps), aged 18-56. Summary statistics presented include the means, standard deviations, ranges, selected percentiles, measures of distribution and coefficients of variation. Also included are statistical variations by age, rank and Corps within the sample, a complete correlation matrix, bivariate tables, and nomographs for various selected combinations of dimensions.

Application of the data to specific design problems is left to the design engineer.

84. Garrett, John W. Anthropometry of the Hands of Male Air Force Flight Personnel.

AMRL-TR-69-42, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 80 pages, 4 references, 1970. (AD 709 883)

This report contains data on 56 anthropometric dimensions of the hands of 148 male Air Force flight personnel found to be representative of the total USAF population. Summary statistics presented include the means, standard deviations, ranges, selected percentiles, and coefficients of variation. Also included are: data on the age, rank, major Air Command and commissioned status of the sample; a complete matrix of intercorrelations among the anthropometric dimensions; bivariate tables; multiple regression equations; and nomographs for selected combinations of dimensions. A tariff for the USAF 12-size glove program revised to reflect the latest anthropometric data is presented in the appendix.

The data in this report and the various statistical relationships provide the designer both with dimensional information and with insight into possible solutions or compromises on specific problems.

85. Garrett, John W. Clearance and Performance Values for the Barehanded and Pressure Gloved Operator.

AMRL-TR-68-24, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 154 pages, 9 references, 1968. (AD 681 457)

This study provides the design engineer with spatial requirements, performance decrements and criteria for the design of controls, handles, and apertures for operators wearing the A/P22S-2 pressure glove. Thirty-six anthropometric and biomechanical measures on the nude hand, on the gloved and unpressurized hand, and on the gloved and pressurized hand, were taken. Subjects were 27 airmen selected to test the full range of 12 glove sizes.

The data for each measure are summarized for all subjects and reported individually by glove size worn. Design applications for each of the measures are suggested and specific figures for each of these applications are recommended.

86. Garrett, John W., Milton Alexander and Chester W. Matthews. Placement of Aircraft Controls.

AMRL-TR-70-33, Aerospace Medical Research Laboratory, Wright Patterson Air Force Base, O., 452 pages, 38 references, 1970.

The intent of this study was to provide the designer of military aircraft with functional arm reach data that would enable hand controls to be so located that they can be operated by both lightly clothed and pressure suited pilots. Seventeen subjects wearing various combinations of personal equipment had their functional reaches measured to 81 different locations within a 180 arc forward of the Seat Reference Point. Subjects were tested while wearing various combinations of personal equipment which included an underarm life preserver, parachute harness, flight coveralls, and uninflated and inflated Full Pressure Suits. Subjects were in a seat approximating Air Force specifications, restrained by a lap belt and shoulder straps with the inertia reel locked and unlocked. Reach values are presented in tabular and graphic form along with recommended design values.

This is an excellent example of a functional reach study, with data presentation in an easily understandable and utilizable form.

87. Garrett, John W. and Kenneth W. Kennedy. A Collation of Anthropometry.

AMRL-TR-68-1, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 1971:Volume I, 1,109 pages (AD 723 629); Volume II, 2,176 pages(AD 723 630).

This two-volume reference work is a critical comparison of measuring techniques and anthropometric data from 32 American and 15 foreign sources. All equivalent and non-equivalent dimensions of the same or similar title (or description) are cited and explicit differences are quoted.

This collation enables the design engineer to find out rapidly and easily which data from different sources are truly comparable and which are not and is of direct use in the design of all types of equipment, workspaces and clothing.

88. Geoffrey, S. P. A 2-D Mannikin--The Inside Story: X-Rays Used to Determine a New Standard for a Basic Design Tool.

Paper presented at the 1961 SAE International Congress and Exposition of Automotive Engineering, Cobo Hall, Detroit, Mich., 59 pages, 1961.

The author reports the procedure and data analysis used to develop a two-dimensional mannikin template representative of a 90th percentile male automotive seated person. Bone length data of Trotter and Gleser (1958) and linkage/bone length ratios of Dempster, et al. (1955) were used to determine limb links. Whole torso x-rays of twelve adult males were taken to locate the spatial relationship between the shoulder and hip joint centers of rotation for erect-seated and car-seated postures. These data were then used to design the mannikin template relative to empirical body linkage data.

This is an important document in terms of both its methodological approach, although crude, and its historical significance in the sequence of studies illuminating the linkage system of the human body.

89. Gifford, Edmund C., Joseph R. Provost and John Lazo. Anthropometry of Naval Aviators - 1964.

NAEC-ACEL 533, U.S. Naval Air Engineering Center, Philadelphia, Pa., 111 pages, 3 references, 1965. (AD 626 322)

Body size data for 96 measurements of 1,549 U.S. naval aviators are presented. Dimensions are given in both centimeters and inches. Statistics included are percentiles, means, standard deviations and coefficients of variation.

Data are presented for use by designers of workspaces, personal protective clothing and equipment.

90. Glumm, Monica M. The Female in Equipment Design.

Highway Safety Research Institute Report #33762, Society of Automotive Engineers, Inc., 400 Commonwealth Dr., Warrendale, Pa. 15096, 6 pages, 6 references, 1976.

With the rapid expansion of womens' participation in all military occupational tasks except combat there is an increasing need to design equipment and develop sizing programs to accommodate women. The author reviews various studies in which critical body dimensions and strength capabilities of men and women were measured and she reports on the results of comparisons between them. Significant differences in dimensions relating to helmets, gas masks and clothing will require considerable modification of sizing programs which are presently geared to a male population, as will criteria for force requirements and distances to controls in the design of cockpits and vehicles. Although emphasis is placed on Army materiel in this report, those determining factors of equipment design are applicable to all areas where women are employed or where their participation is foreseen.

91. Goltz, Eckard and Bernhard Platz. Anthropometric Study.

Report No. T-418, translated from the German by General Motors Corporation Military Vehicles Organization, 24 pages, 1965.

Thirteen measurements were made on 300 subjects from German tank crews. Results, categorized by military task or rank (commanders, drivers and gunners) are presented in frequency tables. A summary table of 5th and 95th percentile values for each dimension is also included.

92. Grether, W. F. "Acceleration and Human Performance."

Aerospace Medicine, 42(11):1157-1166, 43 references, 1971.

Research on acceleration (G), such as experienced in aircraft and space vehicles, is reviewed in terms of effects on human performance capabilities. Almost all such research has been conducted on human centrifuges, with the inertial force vectors in the + direction for seated subjects, and the +G_x and -G_x directions for supine and prone subjects. Visual black-out has become the standard indicator of human tolerance to +G_z acceleration. Other visual functions, namely absolute thresholds, brightness discrimination; visual acuity, and instrument reading all have been found to be impaired at G levels well below physiological tolerance limits, for +G_z, +G_x and -G_x vectors. Motor capabilities, namely tracking, reaction time, reaching, and manipulation, also show impairment at relatively low G levels. Limited data on intellectual or central processes suggest that these are more resistant, but not immune, to effects of exposure to acceleration. Included in the review is discussion of probable mechanisms causing performance impairment.

This is an excellent review article.

93. Grunhofer, H. J. and G. Kroh. A Review of Anthropometric Data of German Air Force and United States Air Force Personnel 1967-1968.

AGARD-AG-205, Advisory Group for Aerospace Research & Development, 7 Rue Ancelle, 92200 Neuilly sur Seine, France, 172 pages, 6 references, 1975. (AD A-010-674)

This document compares anthropometric data of German Air Force and U.S. Air Force flying personnel. Material is based on a survey of 1,400 German subjects conducted in 1967-68, and the 1967 USAF survey of 2,420 subjects. Data presented include comparisons of 153 body dimensions given in summary statistics, percentile tables and tables showing frequency of certain ranges.

Correlation tables for all the German data appear in an appendix.

94. Gundersen, Robert T. and Robert L. Bond. Zero-G Workstation Design.

JSC Internal Note No. 76-EW-1, Lyndon B. Johnson Space Center, National Aeronautics and Space Administration, Houston, Tex., 166 pages, 9 references, 1976.

The history of the design of zero-g workstations is reviewed, together with an evaluation of selected Skylab workstations, the best experience available to date. The intent of the report is to outline procedures for attaining optimum workspace design in zero-g. It was determined that the single best operator position is to "stand" on an adjustable foot restraint platform in the neutral body posture, and use the major muscle groups of the body to achieve the exact position required at any one time for any particular task. The importance of designing for a body size range from the 95th percentile male to the 5th percentile female is stressed. With regard to functional reach it is noted that no special problems are anticipated even for the small females. The use of the adjustable foot restraint and the freedom of body movement afforded by zero-gravity will simplify the designers' task. Size-related problems, if any, will tend to be associated with the larger male operators who may be somewhat cramped in the confined work areas.

This is an excellent, practical introduction to the design of workspaces in zero-g environments.

95. Hansen, Robert and Douglas Cornog. 1958. Annotated Bibliography of Applied Physical Anthropology in Human Engineering.

WADC-TR-56-30, Wright Air Development Center, Wright Patterson Air Force Base, O., 301 pages, 1958. (AD 155 622)

This volume contains condensations of 121 reports in the field of applied physical anthropology. A majority of the summary reports are grouped under three headings: Anthropometry, Biomechanics, and Comfort; a few are included in a general group. Working data and important illustrations as well as essential tables and graphs are quoted directly from the original papers in most cases. A complete index is arranged by author as well as by subject. An additional list of reports (not annotated) is included as background material as are two appendixes containing relevant commentary on seating comfort and anthropomorphic dummies.

This is an excellent collection of the most significant research report summaries in applied anthropometry through 1956.

96. Hart, Gary L., George E. Rowland and Robert Malina. Anthropometric Survey of the Armed Forces of the Republic of Korea.

TR EPT-7, Pioneering Research Laboratory, U.S. Army, Natick Laboratories, Natick, Mass., 118 pages, 30 references, 1967. (AD 640 891)

Body measurements and equipment evaluation data were obtained on a sample of 3,747 military personnel of the Republic of Korea (3,249 Army, 190 Air Force, 141 Navy and 167 Marine). Of the 59 body measurements taken of Korean soldiers, 39 were directly comparable to data previously collected from the U.S. troops. The means of data from U.S. troops exceeded those of Korean soldiers on 33 of the measures, indicating larger physical size in almost all dimensions. Comparisons with dimensions of Thai and South Vietnamese military personnel are also presented as well as comparisons among the various branches of the ROK services.

Attitudes of Korean army personnel toward various pieces of American equipment (including the M-1 rifle, carbine, two-and-a-half ton and quarter-ton trucks, and the steel helmet) were ascertained by rating responses on a seven-point scale indicating ease of handling. Subjects rated the smaller, lighter equipment favorably and reported considerable difficulty in using the larger weapons and equipment.

97. Hay, James G. "The Center of Gravity of the Human Body."

Kinesiology Review III, American Association for Health, Physical Education and Recreation, Washington, D.C., 24 pages, 77 references, 1973.

The author provides an extensive and critical review of most of the literature available on segment weight and center of gravity measured on both living and cadaveric subjects. He is concerned primarily with pointing out the assumptions underlying each of the various studies in terms of measurement technique, accuracy, and sample characteristics. The author emphasizes that all the studies which he reviewed must be used cautiously since none of them can fully satisfy all research requirements.

This is an excellent review with a good bibliography.

98. Hertzberg, H. T. E., Irvin Emanuel and Milton Alexander. The Anthropometry of Working Positions.

WADC TR 54-520, Wright Air Development Center, Wright Patterson Air Force Base, O., 12 pages, 22 references, 1956. (AD 110 573)

A sample of 40 adult males (27 Air Force personnel, 13 civilians) has been measured to ascertain new body size data for various representative working positions. Measurements were taken with the body in the standing, kneeling, crawling and prone positions. Problems met in developing procedures for an anthropometry describing working positions are discussed, along with possible approaches for improved data gathering.

99. Hertzberg, H. T. E. "The Conference on Standardization of Anthropometric Techniques and Terminology."

American Journal of Physical Anthropology, 28(1):1-16, 6 references, 1968.

The author describes proceedings of a conference designed to improve the comparability of anthropometric data from all sources by establishing standards for the many new dimensions required in engineering anthropology, and by developing a terminology that reconciles the new standards with previous usages. The group selected a list of dimensions (though with dissent on type and number) recommended as a minimum for all human biological surveys. Conferees also chose from previous usage a terminological structure whose form, content, and mode of presentation they recommended as standard practice by all anthropometrists. Both official and dissenting lists of dimensions are presented, and the terminological structure is described with examples.

100. Hertzberg, H. T. E. "Dynamic Anthropometry of Working Positions."

Human Factors, 2:147-155, 26 references, 1960.

This paper provides a review of the principles and procedures of workspace design for engineers. It emphasizes that both static and dynamic dimensions, which describe the distances man can reach and the forces he can exert, are essential for the efficient design of workspaces. The fallacy of the "average man" concept is demonstrated. The author recommends and describes the concept of "design limits" (or a "range of accommodation" system) as the preferred means of approaching workspace design. General methods of gathering body size and strength data are outlined and major sources of information noted. A brief discussion of human muscle strength in the weightless state concludes the paper.

101. Hertzberg, H. T. E. World Diversity in Human Body Size and Its Meaning in American Aid Programs.

AMRL-TR-68-113, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 4 pages, 6 references, 1968. (AD 737 412)

This brief review shows conclusively that Americans are significantly larger than Oriental and Mediterranean populations. The author compares data from surveys of Italian, Turkish, Greek, Japanese and S. Korean people with various significant dimensions measured in the 1950 U.S. Air Force survey and demonstrates not only that the foreign populations are below the U.S. 50th percentile in most dimensions but also that their proportions are different in various ways.

102. Hertzberg, H. T. E. and Francis E. Burke. "Foot Forces Exerted at Various Aircraft Brake-Pedal Angles."

Human Factors, 13(5):445-456, 7 references, 1971.

Torque tests of 100 pilots' feet on an instrumental rudder pedal were conducted by the authors. The sample was selected to represent 95-99% of USAF pilots in height, weight and sitting height. Results showed that the highest mean forces were exerted on the pedal when the foot was between 15 and 35 degrees past vertical (in relation to its ankle) for all three cockpit sizes tested and for both neutral and extended leg positions. Comments by 86 subjects on foot and ankle comfort at each angle showed a strong subjective preference for the same arc as a zone for comfortable brake-pedal actuation.

Authors recommend that since the region of high torque output indicates the arc of maximal mechanical advantage of the foot and thus probably the zone of least fatigue, these findings should be considered in the design of any pedal in which maximal integration of pedal action with foot motion is sought.

103. Hertzberg, H. T. E., G. S. Daniels and Edmund Churchill. Anthropometry of Flying Personnel - 1950.

WADC TR 52-321, Wright Air Development Center, Wright Patterson Air Force Base, O., 134 pages, 13 references, 1954. (AD 479 53)

Body size data for 132 measurements of over 4,000 male Air Force flying personnel are presented. Organization of the survey is briefly discussed and the techniques of measurement are illustrated by photographs for the benefit of other anthropologists. Both diametral and surface measurements are included. Dimensions are given in both centimeters and inches.

A description of the statistics and an explanation of their use are given with some discussion of certain statistical shortcuts employed in the reduction of the data. The tabulations include range, mean, standard deviation, coefficient of variation, and 25 selected values from the first to the 99th percentile. Means and standard deviation values for each dimension are also given for nine subgroups categorized on the basis of flight duties.

These data are presented for use by the designers of aircraft, clothing, and equipment.

104. Hertzberg, H. T. E., Edmund Churchill, C. Wesley Dupertuis, Robert M. White and Albert Damon. Anthropometric Survey of Turkey, Greece and Italy.

AGARDograph No. 73, The Macmillan Co., New York, N.Y., 302 pages, 1963. (AD 421 428)

This report describes the tabulated data for 150 body dimensions taken on 3,356 military personnel: 915 Turks, 1,084 Greeks, and 1,357 Italians. Besides body dimensions, the data gathered include sociological and military information, somatotype photographs, skinfold thicknesses with accompanying analyses and estimates of body fat, and other measures on each subject permitting assessment of body composition. The tabulated data include summary statistics for each total national sample and subsample. When available, USAF data are presented for comparison.

105. Hettinger, Theodor. Physiology of Strength.

Charles C. Thomas, Springfield, Ill., 84 pages, 149 references, 1961.

This book is primarily a review of the author's extensive research in the area of static muscle strength. Of particular relevance is a chapter devoted to the discussion of strength in relation to age and sex. Hettinger substantiates the assertion that general muscle strength in women is about two-thirds that of men but warns that this is only an average figure and does not apply to every muscle group. The book briefly discusses topics such as absolute muscle strength, muscle strength related to muscle length, and measurements in muscle strength. The majority of the book is devoted to the discussion of muscle strength training.

106. Hobbs, P. C. An Anthropometric Survey of 500 Royal Air Force Aircrew Heads, 1972.

TR-73137, Royal Aircraft Establishment, Farnborough, Hants, England, 122 pages, 1973. (AD 917 599)

Forty-five head and face measurements were taken in an anthropometric survey of 500 RAF aircrew. Data obtained from these, together with 17 derived measurements, are presented in percentile tables. Selected dimensions from this survey are also compared to measurements taken in an earlier survey of 2,000 RAF aircrew and in anthropometric surveys of subjects from several other NATO countries.

The method used in this survey was photogrammetry, which will enable investigators to measure other dimensions from the permanent record photographs at a later time without recalling the subjects.

107. Holland, George J. "The Physiology of Flexibility: A Review of the Literature."

Kinesiology Review 1968, American Association for Health, Physical Education, and Recreation, Washington, D.C., 13 pages, 136 references, 1968.

This article describes the importance and general characteristics of flexibility. It is assumed that flexibility is an important factor in human performance and that improved flexibility is usually a suitable objective in a conditioning program. Flexibility has been shown to be a highly specific factor; i.e., it cannot be determined whether an individual is generally flexible, except in reference to specific joints. The article is divided into four major categories: (1) Anatomical and physiological factors determining range of motion; (2) Measurement techniques and clinical norms of flexibility; (3) Relationship of flexibility to other variables; and (4) Relationship of flexibility to performance.

This is an excellent review article and should be in the files of anyone interested in range of joint motion.

108. Hugh-Jones, P. "The Effect of Limb Position in Seated Subjects on Their Ability to Utilize the Maximum Contractile Force of the Limb Muscles."

Journal of Physiology, 105(4):332-344, 10 references, 1947.

This paper describes results of experiments designed to determine how the maximum pull or push exertable on an isometric hand control and the maximum push exertable on an isometric foot pedal vary with different control positions relative to a seat. It was shown that, in general, push or pull increases with extension of the acting joint until a maximum is reached just before the joint becomes straight. This "limiting angle" (just before the joint becomes straight) was found to be 160° for knee extension and 135° for elbow extension. These experiments were conducted on six male subjects whose ages ranged from 21 to 36 years and whose weights ranged between 147 and 182 pounds.

This paper is probably the classic in the area pertaining to the effects of limb positioning on muscle strength parameters.

109. Hunsicker, Paul A. Arm Strength at Selected Degrees of Elbow Flexion.

WADC TR 54-548, Wright Air Development Center, Wright Patterson Air Force Base, O., 58 pages, 165 references, 1955. (AD 817 92)

The central concern of this investigation was the testing of 55 young men in 60 arm strength tests in the sitting position and 60 in the prone position. The sample was largely comprised of students selected for comparability to body types commonly found in USAF aircrew. Findings are described, graphed and summarized, and recommendations concerning the design and placement of hand-operated levers in cockpits are offered.

This report also summarizes the strength-testing literature and describes modifications made to enhance the utility of the Kinematic Muscle Study machine which was used to test subjects in this investigation. Further modifications and uses of the machine are suggested.

110. Hunsicker, Paul A. A Study of Muscle Forces and Fatigue.

WADC TR 57-586, Wright Air Development Center, Wright Patterson Air Force Base, O., 47 pages, 15 references, 1957. (AD 131 087)

This investigation was concerned with three aspects of strength-testing and three samples of subjects were employed. All subjects were male students chosen so as to be roughly representative of the range of physical characteristics outlined in the 1950 Air Force Flying Personnel Survey.

The initial testing involved 30 men to determine the arm strength they could exert while seated in a simulated pilot seat. One hundred and twenty tests, covering a variety of wrist positions, elbow flexions and force directions were required of each subject. The second phase of the study produced data on 25 subjects who were tested to determine the amount of strength possible in wrist pronation and wrist supination. The final series of tests was aimed at ascertaining strength decrement over a 42-hour period during which each of six subjects was tested hourly.

Recommendations relevant to the design of hand levers are offered.

111. Hunsicker, Paul and George Greey. "Studies in Human Strength."

Research Quarterly, AAHPER, 28(2):109-122, 89 references, 1957.

The authors survey and assess close to 100 studies dealing with strength testing as it is affected by a number of variables. The relationship of age, skeletal position and body build to strength are discussed at some length. Investigations of other factors such as general state of health, fatigue, training and recovery are described as are studies showing the effect of an increase in muscle strength on joint motion and the effect of exercising one limb on the contralateral limb. Static and dynamic strength are roughly defined and their relationship to each other shown to be low.

Excellent review of the human muscle strength literature up to 1957.

112. Ignazi, G., A. Coblentz, H. Pineau, P. Hennion and J. Prudent. Position du Centre de Gravite chez L'Homme: Determination, Signification Fonctionnelle et Evolutive. (in French)

Anthropologie Appliquee 43/72, Paris, France, 194 pages, 68 references, 1972.

The authors measured the location of the center of gravity and three orthogonal moments of inertia on eleven French adult male subjects. These measurements were made on a compound pendulum with the subject in a standing position. The data are reported relative to axes and planes also used by Santschi, et al. (1966). The authors conclude that the location of the center of gravity in the pelvis for the standing position is a necessary consequence of bipedal locomotion in the upright posture.

113. Ince, N. E., S. Redrup and J. Piper. Anthropometry of 500 Royal Armoured Corps Servicemen 1972.

Report No. 36/73, Royal Aircraft Establishment, Farnborough, Hants, England, 113 pages, 7 references, 1973.

Anthropometric measurements were taken on a sample of 500 British RAC servicemen. Percentiles and summary statistics are given for 96 dimensions, along with a sufficient description of measurement methods to facilitate comparisons with data from similar studies.

114. Ingelmark, B. E. and T. Lewin. "Anthropometrical Studies on Swedish Women."

Acta Morphologica, Neerlandico-Scandinavica, VII(2):145-166, 10 references, 1968.

In this study a series of anthropometric measurements was made on 104 Swedish women divided into two groups: 20-22 year olds and 25-40 year olds. Subjects were student nurses and medical students.

The report consists largely of tables comparing results of the two age groups in length, breadth and girth measurements. Significant differences in stature and some other measurements emerge when the age groups are compared.

Also tabulated are comparisons between the present series and results from earlier studies of Scandinavian women and Swedish men.

115. Ingelmark, B. E. and T. Lewin. "Anthropometrical Studies on Swedish Women in Standing and Sitting Posture."

Acta Morphologica, Neerlandico-Scandinavica, III(2):167-178, 11 references, 1968.

In conjunction with general anthropological studies of 104 Swedish women 20-24 and 25-40 (see previous entry) the authors also investigated the anthropometry of standing and sitting on the same subject population. The present report is chiefly a tabulation of ergonomically important body dimensions in both standing and sitting. Comparisons between the age groups, comparisons of results of this investigation with those obtained in an earlier study of sitting posture, as well as correlations between standing and sitting measurements, are presented and their significance briefly discussed.

116. Jackson, John, Robert Bond and Robert Gundersen. Neutral Body Posture in Zero-G.

Skylab Experience Bulletin No. 17, Lyndon B. Johnson Space Center, National Aeronautics and Space Administration, Houston, Tex., 62 pages, 4 references, 1975.

The authors are concerned with analyzing and interpreting astronaut Skylab experiences relevant to body posture in zero-gravity environments. The information available includes inflight crew comments, postflight debriefings, and inflight photography. It was noted that man's posture in the weightlessness of space differs markedly from his one-g posture. When relaxed in zero-g and acted upon by no external forces the human body tends to seek a neutral position which is essentially a semi-crouched position, neither sitting nor standing. This "neutral body posture" is illustrated in the report which includes the angles of the various joints of the body when in this position. It is recommended that this specifically defined body position should be the basis for the design of future spacecraft crew stations and workstations in order to attain the maximum comfort and efficiency in zero-g man-machine interfaces.

This is an excellent presentation of a concept simple in nature, yet fundamental to design in zero-gravity environments.

117. Janssen, C. G. C. and H. J. Docter. "Quantitative Subjective Assessment of Fatigue in Static Muscle Effort."

European Journal of Applied Physiology, 32:81-86, 5 references, 1973.

Investigators set out to demonstrate the possibility of subjective assessment of fatigue in a static muscle load. Six subjects (male students, aged 20-25 years) performed a static muscle exercise with 25, 35 and 45% of their voluntary maximum force. They quantified their subjective feelings of fatigue by means of an assessment scale.

Differences in assessment of fatigue between the three imposed loads were already significant after one minute in the working period; they became more significant during the remainder of the 2.5-minute period. They differed also in the first minute of recovery. This method of fatigue assessment was found to result in greater discrimination than the method of recording heart rate.

118. Jones, C. E., J. L. Kobrick and H. F. Gaydos. Anthropometric and Biomechanical Characteristics of the Hand.

TR EP-100, Environmental Protection Research Division, Quartermaster Research and Engineering Center, Natick, Mass., 16 pages, 14 references, 1958.
(AD 204 867)

This handbook assembles and synthesizes data from widely scattered sources on the size of the male and female hand and on the types and extent of movements the hand can make. The first section deals with the anthropometric dimensions of the hand and shows the centile distribution of component hand sizes in several military population samples. The second section reviews general data on the biomechanics of the hand in terms of direction, range and forces involved in typical functional movements and presents a small number of specific values.

This paper is specifically designed to be of use to engineers concerned with the design of handwear and manually operated controls and equipment.

119. Jones, Frederic Wood. Measurements and Landmarks in Physical Anthropology.

Bulletin 63, Bernice P. Bishop Museum, Honolulu, Hawaii, 67 pages, 13 references, 1929.

This paper contains a comprehensive list of anthropometric measurements commonly employed for recording characteristics either of the intact body or of individual bones. Descriptions of 95 body measurements are included along with a selected "short list" of 20 measurements deemed by the author to yield a maximum of knowledge concerning the physical type of the subject from a minimum of measuring procedures.

Over half the paper is devoted to detailed descriptions of head and face measurements. Also included in sections on the body, the head and the bones are complete sets of proportion indices for use in studying comparisons of individual and ethnic body types.

120. Jorgensen, K. and Ellen Poulson. "Physiological Problems in Repetitive Lifting with Special Reference to Tolerance Limits to the Maximum Lifting Frequency."

Ergonomics, 17(1):31-39, 12 references, 1974.

The authors describe an experiment in which they took 79 measurements of four male and four female subjects performing repetitive lifting of loads from floor to table. Having determined maximum load for each subject, relative loads of approximately 10%, 25%, 50% and 75% were calculated and lifting with at least three different frequencies was performed with each relative weight.

The maximum lifting frequency of females was found to be 0.7 that of males at the same relative burden. The difference was thought to be attributable to the differences in the capacity of the oxygen transporting system in the two sexes. Results also showed that optimum effectiveness was obtained when subjects lifted loads representing 50% of their maximum lifting capacities.

Of practical use to the designer is a table depicting average values of the upper limit for maximum lifting frequencies according to sex, age, height and body weight of a worker and various relative weights of the loads.

121. Jurgens, H. W., K. Helbig and W. Lengsfeld. Body Measurements of 25-40 Year Old Men Upon Examination of the Anthropometric-Ergonomic Significance of Aging on Changes in Body Shape. (in German)

Research Contract BMVg InSan Nr. 3571-V-072, Ministry of Defense, Documentation Center, Military Affairs Dept., 53 Bonn, Friedrich Ebert Allee 34, Germany, 76 pages, 9 references, 1972.

An anthropometric survey of 2,643 military subjects aged 25-40 years old was taken and results compared with percentile data yielded by a comparable survey of 20-year-old recruits. Fifty-four measurements were made.

The survey showed no significant differences in measures of body length, but considerable differences occurred in the measures of body breadth, depth and circumference as well as in weight. In some cases 50th percentile measurements in the 25-40-year-old group represented the 80th percentile of the 20-year-old group.

Investigators conclude that the changes are a function of aging and caution design engineers against using data taken solely from a limited sample of very young men in calculating dimensions for equipment and workspaces designed to accommodate a range of military-aged personnel.

122. Jurgens, H. W., D. Habicht-Benthin and W. Lengsfeld. Korpermasse 20-jahriger Manner als Grundlage fur die Gestaltung von Arbeitsgerat, Ausrustung und Arbeitsplatz. (in German)

BMVg-FBWM 71-2, Ministry of Defense, Documentation Center, Military Affairs Dept., 53 Bonn, Friedrich Ebert Allee 32, Germany, 63 pages, 6 references, 1970.

This report documents results of an anthropometric survey of 7,144 20-year-old men on whom 43 measurements were made. Results are reported in percentile tables and are accompanied by comparisons of regional and sociological sub-groups within the population. An additional table compares the mean values of selected dimensions from this study with comparable data from earlier German and U.S. surveys.

Variables selected for this survey were chosen for their usefulness in the design of military equipment and workplaces.

123. Kay, W. C. "Anthropometry of Republic of Korea Air Force Pilots."

Journal of Aviation Medicine, R.O.K. Air Force, 9(1):61-113, Seoul, Korea, 1961.

One hundred and thirty-two anthropometric measurements were made on 264 South Korean Air Force pilots aged 23-36. Results, given in percentile values, were compared with comparable data for USAF pilots for purposes of developing clothing tariffs suitable for ROK pilots.

Results of the comparisons indicated that mean values for most dimensions are lower for ROK pilots than for USAF pilots. Also noted were marked differences in proportions of the two groups. For example, USAF pilots were found to be longer-limbed by comparison to their trunks than ROK pilots and heavier by comparison to their statures. ROK pilots have higher foot circumferences by comparison to foot length than do U.S. pilots.

While a particular pressure suit was the focus of discussion in this study, the comparative data is applicable in all areas of design engineering in which these two population groups must be taken into account.

124. Kemsley, W. F. F. Women's Measurements and Sizes.

Cheltenham Press Ltd., Cheltenham, England, 134 pages, 1957.

This book describes an anthropometric survey of 5,000 civilian women ages 18-70, and analyzes the results in detail. The chief object of the study was to assist manufacturers of women's clothing by providing reliable information on a range of measurements and by suggesting a sizing system based on stature, hip girth and bust girth. Detailed sizing charts are provided.

The author also discusses and tabulates the data in terms of relationships between measurements, changes that take place during the lifetime of an adult woman, comparisons with women in American and Dutch surveys, the effect of dress, foundation garments and skin measurements on results, and analysis by age, marital status and occupation.

This book is illustrated by numerous tables and diagrams.

125. Kendall, Henry O., Florence P. Kendall, and Gladys E. Wadsworth.
Muscles: Testing and Function.

The Williams and Wilkins Company, Baltimore, Md., 284 pages, 94 references, 1971.

This book consists of seven chapters pertaining to the fundamental principles in manual muscle testing, joint motions and joint positions, nerve and muscle charts and specific manual muscle tests for individual muscle actions. For each individual muscle for which a test is described, the following information is given: muscle origin, insertion, action and innervation, the subject position, fixation, muscle test, pressure and weakness.

This book should be in the library of anyone involved in the area of muscle testing or evaluation. Especially valuable is Chapter II, Joint Motions and Positions.

126. Kennedy, Kenneth W. Anthropometry and Kinematics in Crew Station Design.

AMRL-TR 72-75, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 12 pages, 73 references, 1972.

This article presents an overview of the relevance of anthropometry and kinematics to crew station design. The author demonstrates the startling magnitude of the variability of body sizes and proportions among military populations of various nationalities and the lesser though significant differences found in the American military population. The author reviews the condition of current anthropometric and kinematic data and concludes that while ample information exists on conventional anthropometry, much remains to be done in the areas of functional anthropometry and kinematics to further the engineer's understanding of the functioning person within a defined workspace. Specific past studies are cited and areas of future investigation suggested.

127. Kennedy, Kenneth W. and Byron E. Filler. Aperture Sizes and Depths of Reach for One- and Two-Handed Tasks.

AMRL-TR 66-27, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 33 pages, 7 references, 1966. (AD 646 716)

This report presents data on: (1) the optimal sizes and locations of maintenance apertures, and (2) man's working-reach distances through such apertures for both shirt-sleeved and pressure-suited conditions. The shirtsleeved sample included 69 subjects selected to represent the body size distribution of the USAF population; the pressure-suited sample consisted of 16 subjects, two for each size of USAF Height-Weight Sizing System. Different apertures tested in the study provided for forward or lateral reaches in the standing or seated positions with one or both arms. In all cases the vertical dimension of the aperture permitted the technician to maintain simultaneous visual and manual contact with the task area.

Data, reported in percentiles, include depth of reach, breadth of aperture, vertical dimension of aperture, and the distances from the floor to both the lower and upper edges of these apertures. Recommendations are made regarding the appropriate application of the data to the sizing and location of maintenance accesses.

128. Kennedy, K. W. Ground Areas Visible from the Aircraft Cockpit Eye Position: A Method of Evaluation.

AMRL TR 68-164, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 10 pages, 1968.

The purpose of this research was to develop a realistic and objective method for comparing aircraft in terms of the ground areas visible from their cockpits. The report describes such a method which consists of calculating the area of the earth's surface visible from the pilot's eye position, within a radius of 3,000 feet and of 18,000 feet. The ground area visible, expressed as a percentage, is regarded as an index of the visibility from the cockpit.

The research was conducted by means of stereophotography with the camera located at the cockpit eye position.

129. Kennedy, Kenneth W. International Anthropometric Variability and its Effects on Aircraft Cockpit Design.

AMRL TR 72-45, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 16 pages, 40 references, 1972. (AD 115 81)

This paper focusses on the problems to be dealt with in accommodating the high-performance single seat military aircraft cockpit to the anthropometric requirements of the foreign military user. The author presents selected data showing the differences in dimensions between U.S. pilots and personnel from selected Oriental and European populations. He describes the applications of these anthropometric differences in cockpit design. Illustrated and discussed are adaptations of the seat, manual and foot-operated controls and personal protective gear which would be required for accommodating several foreign populations.

130. Kennedy, Kenneth W. Reach Capability of the USAF Population.

AMRL TDR-64-59, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 83 pages, 48 references, 1964. (AD 608 269)

This study expands on past investigations which have described various aspects of reach capability with emphasis on the area in front of the operator and limited sectors to the right and left.

The present report contains descriptions of the outer boundaries of the Minimum-, 5th-, 50th- and 95th-percentile grasping-reach envelopes of seated shirt-sleeved operators through 360 degrees in each of the three cardinal planes. The sample contained nine military and 11 civilian subjects representing the general range of USAF personnel in 10 dimensions most relevant to arm reach. Grasping reach envelopes are presented in the form of horizontal sections at five-inch intervals beginning at five inches below the seat reference point and extending to 50 inches above it.

Anthropometric and biomechanical factors most influential in determining the size and shape of the grasping-reach envelope are discussed and applications to the design of workspace and controls are suggested.

131. King, Barry G. "Functional Cockpit Design."

Aeronautical Engineering Review, 2(6):32-40, 1952.

This article stresses the importance of functional anthropometry over classical anthropometry in cockpit design. The author points out, for example, that eye level and sitting height in a natural easy sitting position are about one and a half to two inches lower than the same dimensions measured in the standardized posture normally called for by anthropometrists. Tables showing data for eye level and sitting height measurements as well as for arm reach and forward head movement measurements are included.

132. Kjeldsen, Kirsti. Body Segment Weights, Limb Lengths and the Location of the Center of Gravity in College Women.

Master's Thesis, University of Massachusetts, Amherst, Mass., 57 pages, 25 references, 1972.

The author measured segment volumes and link lengths on 12 college females to estimate segment mass and center of mass. The data are reported as percentages of total body weight or total body height making them comparable to other data in the literature. The definition of the segments were equivalent to Dempster's (1955) for comparison with men and the greatest differences were observed in the calf, thigh and torso (including head).

133. Kroemer, K. H. E. Designing for Muscular Strength of Various Populations.

AMRL TR-72-46, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 51 pages, 93 references, 1974.

This report discusses and presents data on: (1) the magnitude of strength critical for equipment layout; (2) types of strengths required for control operation (twist, squeeze, push, pull, etc.); and (3) strength in relation to control location within the total reach envelope. The author describes techniques and a regimen for the design of new equipment or modification of existing equipment to conform to the strength characteristic of various operator populations.

134. Kroemer, K. H. Eberhard. Human Force Capabilities for Operating Aircraft Controls at 1, 3, and 5 g's.

AMRL-TR 73-54, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 98 pages, 23 references, 1975.

This report contains experimental data on the maximal static forces that subjects could exert at eight locations of hand-operated aircraft controls in two vertical and four to eight horizontal directions at normal gravity and at 3 and 5 g's. The sample was composed of 45 male students and 26 USAF personnel.

Results showed that the amount of force exerable depends on the location of the control, on the direction of force exertion, and on the g-load. In all of the locations, smaller forces were generally exerted in directions perpendicular to a line passing from the handle location to the shoulder of the arm used while larger forces were usually recorded in directions along that line. Similarly, increased g-loads affected forces along this line only relatively little, but had strong effects in directions perpendicular to this line, mainly "up" or "down" in the Z-axis.

Summary statistics for each of 60 exertions are given along with indications, where relevant, whether significant differences exist between the same exertions at different g-loads.

135. Kroemer, K. H. Eberhard. Human Strength: Terminology, Measurement and Interpretation of Data.

AMRL-TR 69-9, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 26 pages, 77 references, 1970. (AD 710 593)

The author describes the limitations of strength testing data and demonstrates that strength data are interpretable and applicable for engineering purposes only if "strength" is defined and if the experimental and statistical procedures used in generating the data are explained. The author also points out that strength data based on maximum exertion by the experimental subjects is of little use in practical applications where operators are not required to exert maximum effort. Also discussed is the need for more research to establish relationships between human static force capacity and the ability to perform dynamic work since, at present, there is little evidence that static force data accurately predict dynamic performance.

136. Kroemer, K. H. Eberhard. Pedal Operation by the Seated Operator.

AMRL-TR 71-102, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 10 pages, 55 references, 1972. (AD 735 315)

This paper summarizes the literature on muscular forces applicable to pedals, and on the efficiency of foot motions on or between pedals. Graphs show maximal leg forces applied to pedals at different pedal heights, knee angles and backrest positions and foot forces achieved in attempted foot rotation at different pedal angles. The author summarizes the findings in terms of their applicability to automobile (or other equipment) design, especially to the design, selection, and arrangement of foot-operated controls.

137. Kroemer, K. H. Eberhard. Push Forces Exerted in Sixty-Five Common Working Positions.

AMRL-TR 68-143, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 70 pages, 69 references, 1969. (AD 695 040)

Experiments were conducted to measure the maximum isometric horizontal push forces exertable in 65 standing positions. The subjects (45 male college students), while pushing horizontally with one hand, both hands, one shoulder, or the back, either anchored their feet against a footrest or braced themselves against a vertical wall. Means, standard deviations, and fifty percentiles of the forces exerted are reported along with a discussion of which positions lend themselves to the exertion of the largest push forces.

138. Kroemer, K. H. Eberhard and J. Michael Howard. "Towards Standardization of Muscle Strength Testing."

Medicine & Science in Sports, 2(4):224-230, 1970.

Because of a variety of techniques and statistical treatments of recorded scores, muscle strength testing data of different origin are often incomparable. In this study, experiments were designed to show how the method of force exertion and the method of evaluating scores can have differing effects on the results of strength tests. To standardize measures of strength, the authors propose a definition of strength, a checklist to control experimental techniques, and a regimen to calculate the strength index.

139. Kroemer, K. H. Eberhard and Danny E. Robinson. Horizontal Static Forces Exerted by Men Standing in Common Working Positions on Surfaces of Various Traction.

AMRL-TR 70-114, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 36 pages, 15 references, 1971. (AD 720 252)

This report describes experiments designed to assess the horizontal push forces subjects can exert in various common working positions under various conditions of floor slipperiness and shoe sole types. Twenty-eight male college students constituted the subject population.

As might be expected, slippery floors and shoe soles limit exertable push forces to very low values. With high-traction floors and shoes, the push force capability depended unpredictably on several other variables. When feet were anchored on a footrest, substantially higher forces were exerted than on any of the flat floor materials. Body weight was found not to be a predictor of force capability.

An appendix contains coefficients of static friction between 19 floor materials and eight shoe materials.

140. Lamphiear, Donald E. and Henry J. Montoye. "Muscular Strength and Body Size."

Human Biology, 48(1):147-160, 1976.

In this analysis, the relationship of arm and grip strength measurements to various anthropometric measurements (height, weight, biacromial diameter, arm girth and triceps skinfold) are considered in both sexes over a broad age range for purposes of facilitating comparisons of strength among individuals irrespective of size differences and to derive sex-age and size-specific standards for evaluating results of strength tests. A simple index of strength is proposed and regression equations are given for the calculation of the comparison standard from measurements of body size by age range for men and women separately.

141. Laubach, Lloyd L. "Body Composition in Relation to Muscle Strength and Range of Joint Motion."

Journal of Sports Medicine and Physical Fitness, 9(2):89-97, 22 references, 1969.

Twenty-seven measurements of body composition, anthropometric dimensions (chiefly skin folds) and physical performance tasks involving strength and range of motion, were obtained from 45 male subjects and the interrelationships among these measures investigated. The sample included college students and employees of Wright Patterson Air Force Base.

Many statistically significant correlations were found between the muscle strength and the body composition measures but none between the range of joint motion and body composition measures. A number of other interrelationships among the measurements are assessed for significant correlation or lack thereof, and multiple regression equations are given for the prediction of physical performance tasks from the anthropometry and body composition measures taken.

142. Laubach, Lloyd L. Characteristics of the Range of Joint Motion and Its Relationship to Selected Anthropometric Dimensions and Somatotype Components.

Microfilmed Ph.D. dissertation, The Ohio State University, Columbus, Ohio, 137 pages, 43 references, 1970.

The primary purpose of this research was to investigate the range of joint motion of male subjects and determine the relationships and interrelationships which exist among these motions and measures of body size, body composition and somatotype. Numerous measurements of joint motion and anthropometry were made of 63 college age male subjects. The data gathered were subjected to a statistical analysis which included descriptive statistics, simple, partial and multiple correlation coefficients, and a factor analysis of the range of joint motion variables.

In general, it was found that the range of joint motion is specific to the particular joint tested and that no one measurement of joint motion can determine the general flexibility of an individual. There is a general lack of relationship between the range of joint motion variables and the body size indicators measured in this study.

143. Laubach, Lloyd L. Muscular Strength of Women and Men: A Comparative Study.

AMRL-TR-75-32, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 106 pages, 20 references, 1976.

Experiments were conducted to measure static muscular strength characteristics of women subjects and compare these results with similar data previously reported for males. Twelve measures of static muscular strength, 22 body-size measurements and the somatotypes of 31 female subjects were investigated. Selected reports in the literature dealing with the comparison of static and dynamic muscular strength of women and men are presented and discussed in some detail. The summary descriptive statistics for the strength measures were compared tabularly and graphically and percentage differences in strength between women and men reported. An analysis of the range and the average mean percentage difference in muscular strength capabilities is presented. The complete intercorrelation matrix for the 38 variables (including age) obtained in this research is shown.

144. Laubach, Lloyd L. and Milton Alexander. "Arm-Reach Capability of USAF Pilots as Affected by Personal Protective Equipment."

Aviation, Space and Environmental Medicine, 46(4):377-386, 12 references, 1975.

Thirty-two USAF pilots participated in a study to determine the effects of personal protective equipment upon arm-reach capability. The reach envelope of each pilot was measured under two experimental conditions: (1) shirt-sleeved with the inertial reel unlocked; and (2) wearing complete winter flying assembly with the inertial reel locked. Selected descriptive statistics are presented for each of five angular positions. Arm-reach envelopes for various percentile values obtained for the two experimental conditions at 10 knob distances from the deck are shown. The results indicate that there are significant practical differences in arm-reach capability between the shirt-sleeved and the complete winter flying assembly conditions.

145. Laubach, Lloyd L. and John T. McConville. "Muscle Strength, Flexibility, and Body Size of Adult Males."

Research Quarterly, AAHPER, 37(3):384-392, 23 references, 1966.

Four measures of muscle strength, two measures of flexibility (range of motion), 30 anthropometric measures, and the somatotypes of 45 male subjects were obtained and the interrelationships among these variables investigated. The sample consisted of college students and WPAFB employees and was comparable in overall body size to the 1950 USAF survey sample. Mean age was 20.7 years.

Many statistically significant correlations were found between the anthropometric and strength measurements but none between the anthropometric and flexibility measurements. The only strength measurement to correlate significantly with flexibility was hip-flexion strength (with hip extension-flexion); the only somatotype component to correlate significantly with the measures of muscle strength was mesomorphy. The correlations between the somatotype components and measures of flexibility were insignificant.

146. Laubach, Lloyd L. and John T. McConville. "Notes on Anthropometric Techniques Anthropometric Measurements - Right and Left Sides."

American Journal of Physical Anthropology, 26(3):367-370, 7 references, 1967.

In order to discover whether statistically significant differences exist between measurements taken on the right and left sides of the body, 21 such anthropometric dimensions were compared. In eight cases, significant differences were found; six of these dealt with the arm in which the dimension measured on the right side was greater. No conclusion could be drawn on the relationship of these data to handedness since relevant information on right or left handedness was lacking. The authors point out that the statistically significant differences between right and left side measurements may not necessarily be of any practical significance and that this is a matter which would have to be evaluated with each problem or application.

147. Laubach, Lloyd L., K. H. Eberhard Kroemer and Marvin L. Thordsen. "Relationships Among Isometric Forces Measured in Aircraft Control Locations."

Aerospace Medicine, 43(7):738-742, 17 references, 1972.

Fifty-one male subjects (chiefly students) participated in a study designed to measure the maximum isometric forces that could be exerted at six locations of hand-operated aircraft controls. The subject sat in a simulated aircraft seat and exerted forces on a cylindrical handle. Forces were measured in two vertical and four to eight horizontal directions. Selected descriptive statistics are presented for each of the 44 force exertion measurements.

The results show that the amount of force exerable depends decidedly on the location of the control and on the direction of force exertion. Correlations among the force exertions at the several locations were low, indicating that the forces exerable at a location must be determined experimentally rather than by statistical analysis of other force data.

148. Laubach, Lloyd L. and John T. McConville. "Relationships Between Flexibility, Anthropometry, and the Somatotype of College Men."

Research Quarterly, AAHPER, 37(2):241-251, 25 references, 1966.

Fourteen flexibility measurements, 63 direct and derived anthropometric measurements, and the somatotypes of 63 college men were obtained in order to assess the relationships between flexibility (range of motion) and anthropometric measurements, anthropometric measurements and somatotype, and flexibility and somatotype. In mean age (19.0) as well as in height and weight measurements, this sample was similar to a sample of 3,299 USAF basic trainees used in an earlier study.

Generally high correlation coefficients were obtained between the anthropometric measurements and somatotypes. Body fat, as measured by skin fold calipers yielded significant negative correlations with flexibility measurements. Correlations between flexibility measurements and anthropometric measurements and between flexibility measurements and somatotype were largely insignificant.

149. Laubach, Lloyd L. and John T. McConville. "The Relationship of Strength to Body Size and Typology."

Medicine & Science in Sports, 1(4):189-194, 31 references, 1969.

Thirteen measures of static strength, 13 body size measurements, and the somatotypes of 77 male subjects were obtained and the interrelationships among these measures were investigated. Summary descriptive statistics are given for the 29 variables studied and the measurements are assessed for significant correlation or lack thereof.

The authors conclude that the measures of body size, somatotype and body composition used in this analysis were not effective predictors of muscle strength as measured by the static-contraction method.

150. Leeper, Robert C., Howard A. Hasbrook and Jerry L. Purswell. Study of Control Force Limits for Female Pilots.

FAA-AM 73-23, Office of Aviation Medicine, Federal Aviation Administration, 800 Independence Ave., Washington, D.C. 20591, 30 pages, 18 references, 1973.

This study was designed to determine maximum strength, and endurance at various levels of strength exertion, of female pilots. The sample consisted of 24 pilots selected to represent the full range of female pilots in terms of age, height and weight. A simulated cockpit was used and subjects were asked to apply force to aileron, elevator and rudder.

Results are tabulated and discussed in detail. In addition to reporting directly observable strength and endurance data, the authors performed a number of statistical analyses to: (1) determine the relationship between endurance time and anthropometric and other variables; (2) develop prediction equations for endurance time based on anthropometric and other variables, and (3) examine the relationship between force exerted and time of endurance.

Federally regulated control force limits for general aviation aircraft were found to be too high for the majority of female pilots.

151. Lewin, T. "Anthropometric Studies on Swedish Industrial Workers When Standing and Sitting."

Ergonomics, 12(6):883-902, 8 references, 1969.

Anthropometry of standing and sitting positions was studied for men and women aged 25-49 years selected at random from a major Swedish industry. The subjects were 87 men and 77 women. Eleven standing and 26 sitting measurements were made and results presented as summary statistics, correlation coefficients and regression tables showing relationships between selected variables.

Authors discuss the implication of the biological differences between men and women for workspace design, not only in terms of the generally higher values for men, but noting also proportional differences. For example, regression and correlation analysis showed that women have a relatively higher elbow height in standing than men which suggests that work tables should be higher for women than for men of the same stature.

152. Lind, A. R., R. L. Burse, J. S. Petrofsky, J. S. Rinehart and P. G. Schmid. The Influence of Posture on Isometric Strength and Endurance, Forearm Blood Flow, and the Blood Pressure and Heart Rate Response to Isometric Exercise.

TR 75 0086, Air Force Office of Scientific Research, Arlington, Va. 22209, 15 pages, 17 references, 1974. (AD/A 004 332)

The influence of posture on isometric muscular capacity was examined on four subjects in the sitting, 45-degrees head-up, recumbent and 15-degrees head-down positions. The maximal voluntary contraction (MVC) of the subjects' hand-grip was unaffected by posture but the endurance time of an isometric contraction held to fatigue at 40 percent MVC was 20 percent longer in the sitting than in any other posture. Blood flow appeared to be the operating factor since the difference in endurance was abolished when the circulation to the exercising forearm was occluded.

The authors suggest that the use of any but the seated position to reduce gravitational stress should be considered with great care since muscular fatigue with its attendant problems of interference with manipulative skills may provide a difference hazard of, as yet, unknown dimensions.

Data in this study are chiefly of use in addressing problems of lift-off and re-entry of space vehicles.

153. Liu, Y. King and Jack K. Wickstrom. "Estimation of the Inertial Property Distribution of the Human Torso from Segmented Cadaveric Data."

In Perspectives in Biomedical Engineering, ed. R. M. Kenedi, University of Strathclyde, Glasgow, Scotland, pages 203-213, 10 references, 1972, (available from NASA Technical Library, Johnson Space Center, Houston, Tex., Call No. R 856.A1 P47 C1).

This paper describes a method for statistically estimating the inertial property distribution of the human torso based on an analysis of the data obtained from segmenting eight cadaver trunks. The implications of these biomechanical data on mathematical simulation and manikin models are briefly discussed especially with respect to dynamic situations.

154. Maclean, A. J. Anthropometric Survey, Australian Army Foot Dimensions.

Headquarters Army Inspection Service, Albert Park Barracks, Melbourne, Australia, 98 pages, 1968.

In this survey of the feet of male Australian soldiers, 28 measurements were taken on a sample of 3,695 subjects representing 11 corps, ranks and ages. Seven girth dimensions, six height dimensions, nine length dimensions, five width dimensions and an indication of the configuration at the back of the heel were measured on both feet. A number of separately recorded details were also taken to indicate the occurrence of foot shapes and relevant deviations.

Sizing based on foot length and joint girth diagonal in a three-percent grading system is recommended and data is presented in terms of bivariate tables, regression graphs and grading tables for each measurement.

Material in this report is for use in designing footwear lasts and in establishing sizing systems and tariffs for procurement.

155. Martin, James I., et al. Anthropometry of Law Enforcement Officers.

NELC/TD 442, Naval Electronics Laboratory Center, San Diego, Calif. 92152, 266 pages, 1975.

A measurement survey of 23 body dimensions critical to the design and sizing of protective equipment was made of approximately 3,000 male law enforcement officers. The anthropometric data were collected in 17 regions throughout the U.S. Data on height, weight and age of an additional 10,000 officers were also obtained. This report presents the results of standard anthropometrical statistical treatments of the information. Matched sampling techniques assure the utility of this information for present and future law enforcement populations as well as for civilian and military communities.

156. Marton, T., F. P. Rudek, R. A. Miller and D. G. Norman. Handbook of Human Engineering Design Data for Reduced Gravity Conditions.

NASA Contractor Report 1726, National Aeronautics and Space Administration, Washington, D.C., 536 pages, 214 references, 1971.

The purpose of this document was to provide handbook material for the use of engineers, designers and human factors specialists during the development and design phases of the manned spacecraft programs. The book is divided into three major categories. The first, on human characteristics, contains static and dynamic anthropometric measurements, psychomotor and psychosensory data, and physiological standards and tolerances. The second section covers material on responses and tolerances of astronauts to a variety of aspects of the intra-vehicular and extra-vehicular space environment (i.e., rotation, toxic and other hazards, weightlessness, etc.). The third section presents data on design aspects of a number of fasteners, manual controls, apertures, etc., contained in the intra-vehicular workspace.

157. McCally, Michael (editor). Hypodynamics and Hypogravics.

Academic Press, London, England, 306 pages, 1968. References listed after each chapter of the book.

This collection of essays provides a discussion of the effects of reduced input states (weightlessness, confinement and inactivity) upon the human organism, reviews the present state of knowledge in this area and collects pertinent material available in the scientific literature. Among its primary objectives is to serve as a basis of information and source material on which manned space flights can be interpreted and evaluated.

The subject matter of the book is presented by physiologic systems: muscular, skeletal, cardiovascular and central nervous systems. The system and its normal structure and function are briefly outlined and the studies which have established or suggested the effects of reduced input states on the particular physiologic system are then presented.

Reference sources are given for the detailed results of the medical experiments performed in recent United States and Russian manned space flight programs, and specific space flight results are discussed in detail by individual authors.

Excellent background reading material on zero-g application.

158. McCann, C., I. Noy, B. Rodden and O. Logan. 1974 Anthropometric Survey of Canadian Forces Personnel.

DCIEM Report No. 75-R-1114, Defense and Civil Institute of Environmental Medicine, Downsview, Ontario, M3M 3B9, 106 pages, 1975.

This report summarizes the findings of an anthropometric survey of Canadian Forces personnel. Thirty-two measurements were taken on 565 subjects proportionally selected to represent all major CF occupations. The data is presented in the form of percentile tables. Correlation and tables and some bivariate tables are also given.

The survey is designed chiefly to provide information for CF clothing designers but includes also a few basic measurements required for human engineering studies and two measurements for use in helmet design.

159. McConville, John T., Milton Alexander and Seth M. Velsey. Anthropometric Data in Three-Dimensional Forms: USAF Height-Weight Sizing Manikins.

AMRL-TDR 63-55, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 114 pages, 15 references, 1963. (AD 411 556)

This report describes the development of data and the sculpturing of manikins for use in designing Air Force protective garments and associated personal equipment, as part of a long-range program to present designers of protective light equipment with a variety of anthropometric data in three-dimensional form. Included is a discussion of the philosophy behind the development of the program, the procedures used in compiling the statistical data and a description of the body forms generated from those data. Information is given concerning the sculpturing techniques used in the fabrication of the body forms.

160. McConville, John T. and Edmund Churchill. Statistical Concepts in Design.

AMRL-TR-76-29, Aerospace Medical Research Laboratory, Wright Patterson Air Force Base, O., 53 pages, 13 references, 1976.

Authors point out the limitations of drafting board manikins, three-dimensional forms or computer simulations constructed from 5th, 50th, or 95th percentile values. This paper demonstrates the fallacies underlying the assumptions that: (1) the proportionality of various individuals is the same and (2) percentiles for body dimensions are additive.

Focussing on the 5th and 95th percentile body forms, where deviations in size and proportionality are most severe, the authors recommend an improved approach to portray the body size of these segments of the population in design problems.

161. McConville, John T., Edmund Churchill, Lloyd L. Laubach and Milton Alexander (consultant). Anthropometry for Respirator Sizing.

Contract No. HSM 099-71-11, U.S. Department of Health, Education and Welfare, Health Services and Mental Health Administration, National Institute for Occupational Safety and Health, 107 pages, 1972.

This report discusses the utility of existing facial anthropometry for commercial respirator design, the preparation of sample respirator sizing programs, and outlines a procedure for evaluation of respirator fit-test performance. The research described was undertaken to further the understanding of the proper sizing and design of respirators for U.S. male and female civilian workers.

Among the authors' conclusions were that: (1) U.S. military surveys provide the most complete and useful data for use in facial sizing problems, (2) differences in head and face sizes which do exist among racial and ethnic subgroups are of little practical significance in respirator design and sizing and, (3) the assumption that the female face is, for face piece design purposes, a small male face has not been adequately validated.

162. McConville, J. and H. T. E. Hertzberg. A Study of One-Handed Lifting.

AMRL-TR-66-17, Wright Air Development Center, Wright Patterson Air Force Base, O., 19 pages, 9 references, 1966. (AD 637 764)

The primary objective of this investigation was to determine by test the best combination of container size and width that the Air Force population can conveniently lift with one hand. The study examined the interaction of the two variables (weight and width) of one-handed symmetrical boxes which subjects were able to lift to a table 30 inches high. No carrying was involved.

The 30 subjects, aged 18 to 39, included military and civilian employees of the USAF and students from two colleges and were chosen to be reasonably representative in height and weight of the male USAF population.

The major result of this study is a formula by which the recommended upper limit of either package weight or package width may be designed so as to enable 95% of the USAF population to lift it.

163. Meyers, H. C., Jr., G. S. Daniels, Edmund Churchill and Norma Roelke.
Body Dimension Changes During Basic Training.

WADC TR 56-458, Wright Air Development Center, Wright Patterson Air Force Base, O., 29 pages, 5 references, 1956. (AD 972 16)

Changes during basic training in the body dimensions of approximately 200 male and 200 female airmen were measured. Weight, stature and eight circumferences were measured weekly during each of the first four weeks and during the eighth and twelfth weeks of training.

The resulting data were analyzed in the hope that changes in proper clothing size which occur during the training period could be predicted in advance. Variability in the changes was found to be too large and the relationships among the changes and the airmen's original dimensions too poor to permit useful predictions.

A complete resume of the results of the investigations are presented here for the guidance of personnel concerned with the design and the issuance of clothing for and to basic trainees.

164. Montagu, M. F. Ashley. A Handbook of Anthropometry.

Charles C. Thomas, Publisher, Springfield, Ill., 186 pages, 857 references, 1960.

This handbook details basic procedures for taking anthropometric measurements of the living human body, the cadaver and the skeleton. Instruments used, methods of using them and positioning of the subject are described and illustrated. A separate chapter on soft-tissue measurement outlines methods of determining body composition and describes various applications of this data.

165. Moroney, William F. and Margaret J. Smith. Empirical Reduction in Potential User Population as the Result of Imposed Multivariate Anthropometric Limits.

NAMRL-1164, Naval Aerospace Medical Research Laboratory, Pensacola, Fla. 32512, 13 pages, 14 references, 1972. (AD 752 032)

The authors demonstrate that the traditional approach to designing workspaces to accommodate the 50th percentile "average man" or even a range of operators from 5th to 95th percentile is not workable when more than one dimension is involved in the design since the approach is based on the premise that individuals with measurement beyond the established range on one anthropometric characteristic will be the same individuals who fall beyond the range in all other anthropometric features. Examining 13 cockpit-related anthropometric features as measured previously on 1,547 naval aviation personnel, it was determined that where one might have expected only 10% of the population to have been excluded, 52.6% were in fact excluded, and where only 5% theoretically should have been excluded 32.2% were excluded.

It is suggested that the preparation of bivariate data which is not variable specific but which could be used when the correlation between variables is known would be a partial solution to resolving problems of anthropometric incompatibility when multiple dimensions are involved in a design.

166. Moroney, William F. and Margaret J. Smith. Intercorrelations and Selected Descriptive Statistics for 96 Anthropometric Measures on 1549 Naval Aviation Personnel.

NAMRL 1165, Naval Aerospace Medical Research Laboratory, Pensacola, Fla. 32512, 101 pages, 9 references, 1972.

This collection of tables makes available to designers the correlations between 96 anthropometric features as previously measured on a sample of 1,547 naval aviation personnel. The data are useful in the design of workspaces in which more than one dimension must be taken into account; they are particularly applicable in determining what percentage of the using population would be excluded.

167. Moroney, William F. Selected Bivariate Anthropometric Distributions Describing a Sample of Naval Aviators - 1964.

Naval Aerospace Medical Research Laboratory, Pensacola, Fla. 32512, 23 pages, 2 references, 1964.

This report extends data previously collected from 1,547 naval aviation personnel by presenting bivariate tables that illustrate the relationship between selected variables. Twenty-one tables contain selected interactions between combinations of the following workspace-related variables: bicep diameter; buttock-knee length; eye height; sitting; functional reach; head height; knee height, sitting; height; and thigh circumference. Summary statistics are presented for each variable.

Purpose of this compilation is to aid engineers in the design of workspaces where more than one dimension must be taken into account in calculating what percentage of the using population can be accommodated.

168. Morrison, J. F., C. H. Wyndham, N. B. Strydom, J. J. Bettencourt and J. H. Viljoen. "An Anthropometrical Survey of Bantu Mine Labourers."

Journal of the South African Institute of Mining and Metallurgy, 68:275279, 5 references, 1968.

Anthropometric measurements were made on a representative sample of 485 Bantu mine laborers drawn from various geographical regions. Seventy-two dimensions were measured on each subject and the results presented in percentile tables.

Comparisons among the Bantu subjects, a series of South African military recruits and a USAF flying personnel population are tabulated. Linear differences between the Bantus on the one hand and the two comparative populations on the other are considerable. All three groups vary from each other in the circumferential dimensions, while average foot and hand dimensions show very slight differences.

Some functional measurements were taken and the authors briefly suggest their application in the design of workspaces.

169. Munro, Ella H. Preparation of Anthropometric Nomographs.

Report No. 184, Environmental Protection Division, Quartermaster Climatic Research Laboratory, Lawrence, Mass., 19 pages, 1952. (AD 199 487)

Interrelationships between selected bodily dimensions and two independent dimensions are presented in the form of seven nomographs constructed on the basis of analyses of the following Army populations: 24,500 white males (stature and weight); 24,500 white males (stature and chest circumference); 8,700 white males (hip circumference and outseam); 8,600 white males (neck circumference and sleeve length); 5,575 white males (ball of foot girth and length); 6,700 black males (stature and chest circumference); and 6,300 white females (cervical height and hip circumference).

Development and use of the nomographs are explained for designers of clothing and personal protective equipment seeking simple practical sources of references of anthropometric data.

170. Newman, Russell W. "The Body Sizes of Tomorrow's Young Men."

Chapter Eight, in Human Factors in Technology, eds. E. Bennett, J. Degan, and J. Spiegel, McGraw-Hill, New York, N.Y., 16 pages, 1963.

The author describes a study in which a declining sample of 2,532 to 800 college men were measured for stature, sitting height, weight, and body fat four times over a period of 18 months. Data are compared to similar data yielded by earlier surveys of 25,000 World War II soldiers and 4,000 servicemen who died in the Korean War. Results show a marked increase in height (1-1/2 inches) and weight (up to 20 pounds) for the most recent college sample. This should have significant effects on the design of clothing, and particularly on the design of limited workspaces such as cockpits, the author points out, since, for example, the sitting height upper limit of 38 inches for potential pilots would exclude only 5% of previous military populations but would exclude 15% to 20% of the subject college population.

Growth trends, based on the samples studied, are presented in tables projected to 1990.

171. Newman, Russell W. Changes in Body Dimensions During Basic Training in Relation to Clothing Sizes.

Report No. 176, Environmental Protection Section, Quartermaster Climatic Research Laboratory, Lawrence, Mass., 25 pages, 1951.

This report analyzes some of the more important bodily dimensional changes which take place in young men subjected to rigorous military training for the first time. A sizable number of the 254 infantry basic trainees studied were found to change dimensions sufficiently during basic training to require alterations in garments sized to their pre-training girths. Five girth dimensions--waist, seat, chest, shoulder and neck--showed the greatest amount of change and were analyzed in detail. The changes occurred largely in men who were either small or large; small men tended to gain and the large men tended to lose.

Prediction equations and tables for estimating girth changes are recommended as a means of issuing properly-sized clothing to men entering the Army.

172. Newman, Russell W. Model and Size Data for the Design of Men's Clothing.

Report No. 217, Environmental Protection Division, Quartermaster Research and Development Laboratory, Natick, Mass., 16 pages, 1953.

Average values for 30 measurements have been presented for a series of approximately 25,000 U.S. Army soldiers. This series has been subdivided into three subgroups on the basis of the following categories: size (chest circumference), model (chest circumference minus waist circumference); and length (stature). Mean values of the resulting subgroups are presented in tabular and graphic form to facilitate interpretation and to suggest a sizing program.

This data is of use to persons charged with designing and procuring clothing for military men.

173. Newman, Russell W. and Robert M. White. Reference Anthropometry of Army Men.

Report No. 180, Environmental Protection Section, Climatic Research Laboratory, Lawrence, Mass., 172 pages, 1951. (AD 215 53)

This report contains 87 regression tables and 78 bivariate charts indicating a wide variety of interrelationships between pairs of dimensions existing in a sample population of 25,000 Army men.

Pairs of dimensions, from a group of 43, were selected on the basis of their usefulness in the sizing and design of clothing and personal protective equipment. Dimensions relating to the head, however, are not included.

174. Noorani, S. E. and C. N. Dillard, Jr. Anthropometric Survey of the Imperial Iranian Armed Forces, Data Collection and Analysis, Volumes I and II.

Technical Report on the Combat Research and Evaluation Center, Imperial Iranian Ground Forces, Teheran, Iran, Volume I, 87 pages; Volume II, 512 pages, 1970.

This detailed work reports results of an anthropometric survey of three branches of the Imperial Iranian Armed Forces. A total of 97 dimensions were measured on 9,417 subjects. Results of each measurement are presented as summary statistics and frequency tables. Also included in the statistical analysis are extreme value tables and bivariate tables of selected variables relevant to the fit of clothing. General characteristics of the subject population (such as ethnic derivation, place of birth and rank) are also tabulated.

Aim of the survey was to provide a basis for determining how to improve the fit of uniforms and to develop procurement tariffs for them.

175. Nordgren, Bengt. "Anthropometric Measures and Muscle Strength in Young Women."

Scandinavian Journal of Rehabilitation Medicine, 4:165-169, 6 references, 1972.

Anthropometric data and maximal isometric muscle strength were recorded in 23 healthy women, mean age 20 years. These data were compared with those from a group of healthy young men. The muscle strength was lower (most pronounced in the upper extremities) in the female group. Except for the skinfold thickness, which is significantly larger in the women, the difference in anthropometric data between the two groups was much less than the difference in muscle strength. Most anthropometric measurements were smaller in the female group. When predicting the body weight the width of the femoral condyle would seem to be preferable to the body height.

176. O'Brien, Ruth and William C. Shelton. Women's Measurements for Garment and Pattern Construction.

U.S. Department of Agriculture Miscellaneous Publication No. 454, U.S. Government Printing Office, Washington, D.C., 73 pages, 1941.

Fifty-nine measurements of 10,042 white women were taken in this study undertaken for the purpose of improving the fit of women's garments and patterns. Results are presented in tables covering the summary statistics as well as in frequency distribution and bivariate tables.

A sizing system based on height and weight is recommended by the authors and figures for establishing such a system are given. Also included are data for four alternative sizing systems based on height and each of four selected girth measurements.

While now out of date, results of this survey represent the most comprehensive clothing anthropometry of U.S. women ever undertaken.

177. Oshima, M., et al. Anthropometry of Japanese Pilots.

AMRL-TR-65-74, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 114 pages, 1965. (AD 462 062)

This report presents the results of a body size survey conducted by Japanese flight surgeons in the spring of 1961. Sixty-two measurements were taken on 239 pilots of the Japanese Air Self-Defense Force at five different bases in Japan. Data reported include the mean, standard deviation, coefficient of variation and percentiles of each measurement. Also included are statistical comparisons between the Japanese and USAF flying populations.

A four-size height-weight program for JASDF pilots is presented for use by protective equipment designers.

178. Peters, Von T. "Anthropometrische und Physiologische Grundlagen zur Gestaltung von Buroarbeitssitzen" (in German).

Ergonomics, 12(2):162-170, 31 references, 1969.

An anthropometric study of 1,166 German female office workers was undertaken for the purpose of obtaining information for improving the design and construction of office furniture.

Ten standing and sitting dimensions were measured from the right and left (where relevant) and with subjects erect and relaxed. Results are presented in a table showing mean values and standard deviations for each measurement. A numbered illustration makes clear to the non-German reader which dimensions were measured.

179. Petrofsky, Jerrold S. and Alexander R. Lind. "Aging, Isometric Strength and Endurance, and Cardiovascular Responses to Static Effort."

Journal of Applied Physiology, 38(1):91-95, 16 references, 1975.

This investigation assessed the maximal handgrip strength, the duration of a fatiguing handgrip contraction at a tension of 40% of maximal strength and the heart rate and blood pressure during that contraction of 100 men aged from 22 to 62 years. The subjects of this study were men employed in a machine shop for a large aircraft corporation. The homogeneity of their occupations may well explain why, unlike previous reports, the authors found no change in muscular strength or muscular endurance with age. However, although heart rate increased during the contraction in all subjects, the increase in heart rate was greater in younger men. In contrast, while both systolic and diastolic blood pressures increased during the contraction in all subjects, the largest increase in systolic blood pressure was attained by the men in the older decades; there was no difference due to age in the diastolic blood pressures. The implications of these findings are discussed.

180. Prokopec, M. "Dimensional Characteristics of Men and Women in Czechoslovakia for the Purposes of Industry."

In: Ergonomics in Machine Design, Volume I, International Labour Office, Geneva, Switzerland, 18 pages, 9 references, 1969.

This paper contains a brief review of anthropometric surveys conducted on Czechoslovakian children and adults in the past 25 years. Of interest to users of this data book are selected charts and illustrations giving: (1) mean results from measurements of 27 dimensions of 1,110 lumbermen aged 25-45 years, (2) changes in a dozen body measurements between ages 18 and 72, (3) head and face measurements of adult men and women, and (4) mean height, weight and chest circumferences of adult men (over 45) and women (over 18).

181. Randall, Francis E., Ella H. Munro and Robert M. White. Anthropometry of the Foot.

Report No. 172, Environmental Protection Section, Quartermaster Climatic Research Laboratory, Lawrence, Mass., 23 pages, 1951. (AD 103 423)

Data from an earlier anthropometric survey of the feet of 5,575 white Army males were used to develop a better means of sizing and fitting shoes than had heretofore been in use. While the older method had been based on foot length and ball breadth horizontal measurements, the authors found, upon analysis of the anthropometric data, that ball length and ball girth would more accurately control the fit of the shoe because of closer interrelationships with other critical dimensions of the foot. Reference data are provided in the form of tables and a nomograph for application of these relationships in the construction of lasts and shoes.

In order to illustrate the actual procedure which should be followed in applying the required data from the nomograph, a sample problem is presented in some detail.

182. Randall, Francis E. An Anthropometric Nomograph for Army Men.

Report No. 147, Environmental Protection Section, Quartermaster Climatic Research Laboratory, Lawrence, Mass., 20 pages, 1949.

Analysis of an Army population of 24,576 white males was made in order to develop a nomograph from which can be easily read the average values of 24 dependent dimensions associated with any selected pair of stature and chest circumference values. The objective was to provide a simple source of reference of anthropometric data for use by designers of Army clothing and other personal equipment.

183. Randall, Francis E., Albert Damon, Robert Benton and Donald Patt. Human Body Size in Military Aircraft and Personal Equipment.

TR 5501, Army Air Force, Air Materiel Command, Wright Field, Dayton, Ohio, 333 pages, 75 references, 1946, Reprinted 1963. (ATI 254 19)

This report deals with the relation of human body size to military aircraft, equipment and clothing. It contains a mass of measured data and suggested applications covering clothing size and design, seating, emergency exiting, eye sighting, and three-dimensional manikins among other subjects. Summary statistics and percentile tables are given for anthropometric measurements taken on 2,959 flying cadets, 584 gunners and 446 women flying personnel.

Emphasis is on the functional person considered in the air crew position. While specific items of Army Air Force clothing and equipment are cited and used in obtaining measurements, much of the discussion in this report centers on the application of anthropometric data to problem solving in human engineering and is of value to designers of any aircraft and associated equipment.

This is the only complete source for results of WWII anthropometric studies by the U.S. Army Air Force, and it lays the foundation for all future efforts.

184. Randall, Francis E. and Ella H. Munro. Reference Anthropometry of Army Women.

Report No. 149, Environmental Protection Section, Climatic Research Laboratory, Lawrence, Mass., 240 pages, 1949. (AD 209 837)

This report contains 109 regression tables (each showing averages of one dimension associated with given values of a second dimension for tailoring purposes) and 98 bivariate tables indicating a wide variety of interrelationships of pairs and dimensions existing for a sample military women's population. Figures are based on the results of a 1946 survey of 4,445 enlisted WAC's, 484 commissioned WAC's and 3,614 Army nurses. Of 65 dimensions measured in the survey, 51 are considered in varying detail in this report.

Selected variables are those of use primarily to designers of women's clothing and personal protective equipment.

185. Randall, Francis E. and Melvyn J. Baer. Survey of Body Size of Army Personnel, Male and Female: Methodology.

Report No. 122 (Revised), Environmental Protection Branch, Climatic Research Laboratory, Lawrence, Mass., 44 pages, 1951. (AD 149 458)

This report is wholly devoted to describing the measurement techniques used in a survey of 105,062 Army men in 1946. Verbal descriptions are given for each of 64 measurements.

186. Randall, Francis E. Survey of Body Size of Army Personnel, Male and Female: Phase 4, Body Dimensions of Army Females.

Report No. 123, Environmental Protection Section, Climatic Research Laboratory, Lawrence, Mass., 36 pages, 1947.

Although this report describes the 80 dimensions measured in a survey of 8,259 Army women, only results of age, stature and weight measurements are tabulated here. Also included are distribution tables. Subjects are categorized by position in the Army (enlisted, officer or nurse) and by geographical origin.

187. Rebiffe, R. (translated from the French by W. F. Fielding). The Driving Seat: Its Adaptation to Functional and Anthropometric Requirements.

Library Translation 1841, Royal Aircraft Establishment, Farnborough, Hants, England, 22 pages, 11 references, 1975.

Using the driving seat as an example, the authors outline a detailed methodology for designing a seat to achieve maximum comfort and safety for the occupant and allow him optimum function for the task at hand. Emphasis is on the dynamics of the operator in relation to his task.

Chief factors in seat design are seat height, location and extent of the adjustment zone, seat back inclination, cushion inclination, and static consistency of the cushion.

188. Reynolds, Herbert M. and Mackie A. Allgood. Functional Strength of Commercial Airline Stewardesses.

Department of Transportation, Federal Aviation Administration, Office of Aviation Medicine, Civil Aeromedical Institute, Oklahoma City, Okla. 73125, 22 pages, 20 references, 1976.

Results of 13 body measurements and four strength tests are reported in this study of 152 female flight attendants. Stewardesses were found to be taller, lighter and slendrer than women of corresponding age in the civilian and military populations. Strength tests, which included a leg lift, a back lift, an arm lift and a push exertion, were designed to provide engineers with data on maximum static forces that stewardesses could employ at various work levels in commercial aircraft.

Strength data are reported in terms of average plateau, maximum force and pound-second force.

189. Roberts, Lester B. Size Increase of Men Wearing Various Clothing Combinations.

Project No. 9, SPMEA 741-3, Armored Medical Research Laboratory, Fort Knox, Ky., 12 pages, 1945.

This report consists of two tables and nine accompanying figures showing changes which occur in a number of body dimensions with the addition of various combinations of military clothing.

190. Roebuck, J. A., Jr., K. H. E. Kroemer, and W. G. Thompson. Engineering Anthropometry Methods.

John Wiley & Sons, New York, N.Y., 459 pages, 549 references, 1975.

This comprehensive manual presents methods for both measuring and applying data on human body dimensions and strength to engineering design. Among the areas covered in this book are: static and dynamic measurement methods and instruments; rules of thumb concerning body proportional relationships and population characteristics; statistical data reduction and analysis of trends; and techniques for applying data to the design of workspaces, clothing, small components and devices.

This is probably the most thorough and comprehensive book in its area and is a highly recommended source.

191. Rohmert, W. and P. Jenik. "Isodynes of Women in the Reaching Area of the Arms."

International Journal of Production Research, 11(1):11-20, 7 references, 1973.

This article describes a means of diagramming results of muscular strength tests of women. Ten subjects were asked to exert maximum force on a straining gauge dynamometer in various directions and in various arm reach positions. Isodynes are curves which join points within arm reach and which indicate strengths of the same type and amount; the isodyne diagrams are designed to indicate a total picture of arm reach strength capabilities created from a few measurements. Those presented here are useful to designers of workspaces in indicating maximum values of female muscular arm strength with the arm in various positions.

192. Rohmert, W. and P. Jenik. "Isometric Muscular Strength in Women."

Chapter Four in Frontiers of Fitness, by R. J. Shephard (ed), Charles C. Thomas, Springfield, Ill., 18 pages, 11 references, 1971.

This paper reports measurements of isometric muscular strength of ten women between 17 and 24 years of age. Strength measurements included maximum lifting strength of both arms, foot pressure exerted by the right leg from a sitting position, central push and pull of the arm, and adduction pull and abduction push of the arm within arm reach and from a standing position. The results were compared with data previously obtained from men. Rohmert and Jenik report the mean strength difference between women and men to be about the classical value of two-thirds; however, they warn that the wide range of strength differences between women and men prohibit the use of this figure ($2/3$) as an estimate for all subjects.

This is an excellent piece of research containing a lot of data on strength differences between women and men.

193. Roth, Emanuel M. "Anthropometry and Temporo-spatial Environment."

In: Compendium of Human Responses to the Aerospace Environment Volume III, NASA CR 1205 (III), National Aeronautics and Space Administration, Washington, D.C., 130 pages, 380 references, 1968.

This chapter summarizes a broad spectrum of anthropometric data relevant to the design of clothing, equipment and work places in space vehicles. Of particular interest to NASA engineers are statistical data on 162 anthropometric measurements taken from a variable population (from 3 to 38) of astronauts.

Other sections cover centers of gravity and moments of inertia, workspace dimensions, strength, and changes in measurement, visual field and mobility resulting from wearing various pressure suit assemblies.

194. Salter, Nancy and H. D. Darcus. "The Effect of the Degree of Elbow Flexion on the Maximum Torques Developed in Pronation and Supination of the Right Hand."

Journal of Anatomy, 86:197-202, 6 references, 1952.

Maximum torques that can be developed isometrically in attempted pronation and supination were determined with the hand in six positions between full pronation and full supination and with the elbow flexed in three positions (30 degrees, 90 degrees and 150 degrees). Subjects of the study were three naval ratings.

Results of the experiments confirmed that there is a linear relationship between the position of the hand and the isometric torque developed and that as the position of the hand alters in the direction of supination, the isometric pronation torque increases and the supination torque decreases; the converse was also found to be true. In all subjects, both pronation and supination were strongest at 90 degrees elbow flexion and generally weakest with the elbow flexed at 150 degrees. At the mid-point of the full range of movement, pronation was stronger than supination in eight cases and the same in one.

Data in this study is useful in the design of manual controls.

195. Santschi, W. R., J. Dubois and C. Omoto. Moments of Inertia and Centers of Gravity of the Living Human Body.

AMRL-TDR-63-36, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 62 pages, 11 references, 1963. (AD 410 451)

A study was conducted to determine the moments of inertia and centers of gravity of a sample of 66 living male subjects (employees of North American Aviation, Inc.) representative of the Air Force population in stature and weight. Eight body positions were investigated: standing, standing with arms over head, spread eagle, sitting, sitting with forearms down, sitting with thighs elevated, Mercury configuration, and relaxed (weightless). A set of 50 anthropometric dimensions was taken on each subject as well as photographs of each subject in each position. Results of a brief statistical analysis indicate, among other things, that moment of inertia correlates very well with subject stature and weight in all positions and axes.

The data contained in this report provide a basis for total-body dynamic analysis. Relative to the test sample or other similar populations, individual centers of gravity can now be estimated and moments of inertia computed from easily obtainable anthropometric dimensions.

196. Schane, W. P., D. E. Littell and C. G. Moultrie. Selected Anthropometric Measurements of 1,640 U.S. Army Warrant Officer Candidate Flight Trainees.

USAARL Report No. 69-2, U.S. Army Aeromedical Research Laboratory, Fort Rucker, Ala., 70 pages, 6 references, 1969.

The results of nine anthropometric measurements conducted on 1,640 U.S. Army warrant officer candidates are presented in percentile tables, bivariate tables, histograms and nomographs. Comparisons of data with similar measurements made upon flying personnel in other military studies are shown.

The measurements made in this study were selected as those most relevant to aircrew workspace design in aircraft.

197. Sendroy, Julius Jr. and Louis P. Cecchini. The Determination of Human Body Surface Area from Height and Weight.

Project NM 004 006.05.01, Naval Medical Research Institute, National Naval Medical Center, Bethesda, Md., 17 pages, 32 references, 1954. (AD 448 29)

A simple, rapid and accurate method of calculating human body surface from height and weight has been developed by the authors. From the relationships of height plus weight and the "shape" factor of the ratio of weight to height, charts have been constructed for the graphical estimation of surface area values in the range from .05 to 3.0 m². From these master charts a diagram has been constructed whereby surface areas may be obtained with the same accuracy and more conveniently from values of height and weight alone. This diagram is included in the report in suitably enlarged form to facilitate its use.

198. Simons, J. C. and W. Kama. A Review of the Effects of Weightlessness on Selected Human Motions and Sensations.

AMRL Memorandum P-36, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 22 pages, 18 references, 1963. (AD 282 116)

Data in this study, obtained in a large-cabin-volume aircraft flying 14-30 second weightless trajectories, are largely out-of-date and only of peripheral concern to the subjects covered in this data book. It is included because joint angles of the relaxed body posture, hypothesized from experimental data in this study and given here, are usable approximations for calculations involving the posture of persons in a zero-gravity environment.

199. Simpson, R. E. Specimen Size Rolls for Aircrew Headgear Based on an Analysis of the Head Measurements of 2,000 Royal Air Force Aircrew.

Technical Report 74072, Royal Aircraft Establishment, Farnborough, Hants, England, 120 pages, 1974.

Head measurements obtained during the 1970-71 anthropometric survey of 2,000 RAF aircrew have been processed to provide size-roll data in a form suitable for use by headgear designers. Sample size rolls are presented which are based on the sizing control measurements thought likely to meet the requirements of the headgear designers.

Selection of the most appropriate sizing control measurements by the designer will be influenced by many factors depending on the type of headgear and critical fit measurements. Some guidance on control measurement selection is offered in the discussion.

Summary statistics and percentile tables for 20 head and face measurements are included in this report.

200. Simpson, R. E. and C. B. Bolton. An Anthropometric Survey of 200 R.A.F. and R.N. Aircrew and the Applications of the Data to Garment Size Rolls

TR 67125, Royal Aircraft Establishment, Farnborough, Hants, England, 108 pages, 4 references, 1968.

This report deals mainly with the collection, presentation and application of anthropometric data required for the production of close-fitting garments. Some additional data with application to workspace design are also included.

Forty-four measurements on 200 RAF and RN aircrew were obtained. Summary statistics and tables of percentile values are presented. Comparisons between several types of sizing systems are made and the authors recommend that a sizing system for one-piece garments in which a good torso fit is essential should be based on two direct body measurements such as chest girth and torso hoop (vertical trunk circumference) rather than on one or more indirect measurements such as weight or stature. If torso fit is unimportant, it is logistically more advantageous, according to the authors, to use chest girth/stature or weight/stature as the control measurements, the latter being preferred.

201. Sittig, J. and H. Freudenthal. De Juiste Maat (in Dutch).

N.V. Magazijn "Die Beijenkorf," Uitgegeven Bij L. Stafleu, Uitgever Te Leiden, The Netherlands, 402 pages, 1951.

An anthropometric survey of 5,001 Dutch women yielded data on 15 bodily dimensions for purposes of improving the sizing of civilian clothing. Results are given in the form of one- and two-dimensional frequency distributions and simple and multiple correlation coefficients selected for their capacity to typify the human figure.

A comparison of Dutch data with results of similar studies conducted on U.S. women shows significant differences in dimension and proportion between Dutch and American women. While American investigators concluded that womens' bodily dimensions are best typified by height and weight, the authors conclude that an optimum sizing program for Dutch womens' clothing should be based on waist girth and back length.

While this book is written in Dutch, it contains a summary in English and provides, in English, explanations of the tables and figures in which much of the data are presented.

202. Smiley, J. R. AGARD Body Measurements of 1578 RCAF Aircrew Trainees.

IAM Report #58/1, Institute of Aviation Medicine, 1107 Avenue Road, Toronto, Ontario, Canada, 19 pages, 3 references, 1958. (AD 809421)

Seven anthropometric measurements basic to the determination of workspace dimensions for aircrewmen were made on 998 pilots and 580 observers. Measurements were taken on subjects in the nude and, later, fully dressed in winter gear.

Results of the nude measurements are presented in summary statistics as well as in the form of correlation coefficients for each of the 21 pair combinations of the seven variables. Comparisons of RCAF data with USAF data yielded no practical significant differences.

Investigators also examined the effect of aircrew clothing on body measurements. Such clothing was found to increase sitting height, leg length and seat breadth by an average of two inches each. The average increase of thigh length was one-half inch.

Data in this report are useful for determining the extent to which body dimensions are modified by heavy clothing.

203. Snook, S. H. "The Effects of Age and Physique on Continuous-Work Capacity."

Human Factors, 13(5):467-479, 37 references, 1971.

Twenty-eight male industrial workers, 14 between 25 and 35 years of age, and 14 between 45 and 60 years of age, performed 54 manual handling tasks, including lifting, lowering, pushing, pulling, carrying and walking exertions. The continuous-work capacity of each subject for each task was measured by a psychophysical technique which required subjects to adjust their work loads to the maximum amount that they could perform without strain or discomfort. Heart rates were monitored continuously during work performance.

Results showed that continuous-work capacity does not decrease with increasing age and that only in the younger group of subjects did physique have a greater effect on continuous-work capacity during slower heavier tasks than during faster lighter tasks. For the older subjects, physique apparently had a greater effect on the faster-paced tasks.

204. Snook, Stover H. and Vincent M. Ciriello. "Maximum Weights and Work Loads Acceptable to Female Workers."

Journal of Occupational Medicine, 16(8):527-534, 15 references, 1974.

The subjects in this study were 16 housewives and 15 female industrial workers who performed 3 lifting, 3 lowering, 4 pushing, 1 pulling, 1 walking, and 6 carrying tasks. The study was identical to an earlier study conducted by Snook and co-workers on male industrial workers, thereby allowing direct biomechanical comparisons between women and men. Twelve tables of data reporting results of the above-mentioned tests are presented in percentile form for industrial men, industrial women and housewives. Comparisons show that the average weight handled by industrial men was significantly greater than the average weight handled by industrial women, which in turn was significantly greater than the average weight handled by housewives.

205. Snow, Clyde C., Herbert M. Reynolds and Mackie A. Allgood. Anthropometry of Airline Stewardesses.

Report No. FAA-AM-75-2, Department of Transportation, Federal Aviation Administration Office of Aviation Medicine, Civil Aeromedical Institute, Oklahoma City, Okla. 73125, 103 pages, 8 references, 1975.

This report presents the body measurements of 423 stewardesss trainees. It includes the means, standard deviations, coefficients of variation, percentiles and related statistics of 72 standard anthropometric and functional measurements.

This survey was aimed at providing adequate criteria for improving the emergency equipment availability and workspace design for the stewardess.

206. Snow, Clyde C. and Richard G. Snyder. Anthropometry of Air Traffic Control Trainees.

Report No. AM 65-25, Federal Aviation Agency, Office of Aviation Medicine, Civil Aeromedical Research Institute, Oklahoma City, Okla., 26 pages, 17 references, 1965.

This report presents the body measurements of 684 air traffic control trainees (aged 21 to 46) enrolled in training programs. It includes the means, standard deviations, coefficients of variation, percentiles and related statistics of 60 standard anthropometric and functional measurements. The survey was initiated to provide adequate criteria for improving the workspace design for the air traffic controller and to provide anthropometric baseline data for future biometric and aging studies of Air Traffic Service personnel.

207. Snyder, Richard G., Don B. Chaffin and David R. Foust. Bioengineering Study of Basic Physical Measurements Related to Susceptibility to Cervical Hyperextension Hyperflexion Injury.

Highway Safety Research Institute, The University of Michigan, Ann Arbor, Mich. 48105, 321 pages, 99 references, 1975.

Reported in considerable detail are results of a study designed to: (1) obtain comprehensive head and neck anthropometry, (2) measure sagittal plane (backward and forward) range of motion of the head and neck, (3) determine the response of head and neck muscles to low levels of acceleration and (4) measure the voluntary isometric strength of neck flexor and extensor muscles. Subjects were 180 civilian volunteers, aged 18-74, categorized by sex, age group and stature and chosen to represent the U.S. adult population as a whole.

The experimental data for the range of motion and muscle strength were used to construct a computerized model. Both experimental and modelling results suggest that the neck muscles can influence neck dynamic responses to varying degrees for different population groups. Aging, sexual differences in cervical mobility, reflex time, and muscle strength were all found to be important factors in injury susceptibility.

Data are presented in a format usable in the design of biomechanical models, anthropometric dummies and crash protection devices.

208. Staples, M. L. A Bibliographical Survey and Critical Review of the Role of Anthropometry in the Sizing of Clothing and Personal Equipment.

GAO-373, Defense Research Board, Ottawa, Canada, 217 pages, 1961.

This report presents a survey and critical review of the literature on the role of anthropometry in the sizing of clothing and personal equipment. In the selection of references, emphasis has been placed on publications dealing with the development of sizing systems and closely related topics.

The report is in four sections. Part I contains brief abstracts of each of the 338 publications that were reviewed. In Part II, the literature is sorted under specific headings to facilitate references to various aspects of the subject. Part III contains a summary of systems that have been proposed for standardizing sizes, with particular reference to the two most common approaches--indirect controls (two measurements such as height and weight not directly involved in the fit of the garment) and direct controls (two or more highly variable dimensions at which a close fit of the garment is important). Part IV contains an assessment of the various sizing systems described.

This is an excellent source of annotations of the significant literature in applied anthropometry.

209. Stewart, T. D. (ed.). Hrdlicka's Practical Anthropometry (3rd ed).

The Wistar Institute of Anatomy and Biology, Philadelphia, Pa., 230 pages, 253 references, 1947.

This is an updated and somewhat reorganized edition of Hrdlicka's classic textbook on the subject. Detailed directions for how to measure the human body and its skeleton are given along with a description of instruments to be used and instructions for determining a number of physiological and nonmetrical characteristics of the body.

210. Stoudt, Howard W., Albert Damon, Ross McFarland and Jean Roberts. Weight, Height and Selected Body Dimensions of Adults, United States, 1960-1962.

Public Health Service Publication No. 1,000-Series 11, No. 8, U.S. Government Printing Office, Washington, D.C. 20402, 44 pages, 64 references, 1965.

Findings from 12 of the 18 measurements of body size taken during Cycle I of the Health Examination Survey of the U.S. civilian population are presented in this document. Subjects of the study were 6,672 men and women, 18 to 79 years of age, representative of the U.S. population as a whole. Dimensions reported on here are height, weight, erect and normal sitting height, knee and popliteal height, elbow rest and thigh clearance height, buttock-knee and buttock-popliteal length, elbow-to-elbow breadth, and seat breadth. Results are tabulated and discussed.

Comparisons are made with findings from previous anthropometric surveys of civilian and military groups in the U.S. and Canada. The possible influence on the findings of such factors as age, racial and ethnic differences, secular changes in body size, socioeconomic differences, civilian and military differences, and differences in measuring techniques which have been noted in previous studies are also discussed. Percentile tables are included for each dimension measured.

211. Stoudt, Howard W., et al. Static and Dynamic Measurements of Motor Vehicle Drivers.

Report No. HS-800 261, National Highway Safety Bureau, U.S. Department of Transportation, Washington, D.C., 237 pages, 20 references, 1970.

This multiple-phased study is concerned with human dimensions relevant to the task of operating a vehicle. The most important elements in the human engineering of seat and vehicle, according to the authors, are visual efficiency, seat comfort, spatial clearances around the body, reach to hand and foot controls, and protection, chiefly by way of restraint systems. In the first part of the study, 22 static dimensions were measured on a population of 524 females and 509 males representative of the range of the U.S. civilian population. The report contains graphic and tabular representations of the resulting data for the first through 99th percentile subjects.

The fourth phase of the study concerns functional arm reach data derived from measurements of 100 male and female subjects. Data for 117 reach positions are tabulated for first through 99th percentile subjects.

Sections on pregnant females and sub-adults are also included but not relevant to the subject at hand.

212. Strydom, N. B., J. F. Morrison, C. H. van Graan, J. H. Viljoen, and A. J. A. Heyns. "Functional Anthropometry of White South African Males."

South African Medical Journal, 42:1332-1335, 10 references, 1968.

Anthropometric measurements, including a number of functional measurements, were made on a military population of 1,449 white South African males aged 17 to 61. Means, standard deviations and 95th, 50th and 5th percentiles are given for 58 different measurements.

Presentation of the data is largely by age group and findings confirm other studies in which stature is shown to remain relatively constant while body depth, waist circumference and skinfolds increase almost linearly with age.

213. Swearingen, John J. Determination of Centers of Gravity of Man.

AOM 62-14, Federal Aviation Agency, Civil Aeromedical Research Institute, Oklahoma City, Okla., 37 pages, 2 references, 1962.

Five adult males, representing a wide range of body sizes, were the subjects in this study of center of gravity (CG) of the human body in 67 body positions. Analysis of tests of maximum shift of CG (with limbs, head and torso flexed and extended in various directions around the fixed pelvis) showed that CG can be shifted as much as 11.5 inches toward the head, 10 inches toward the feet, 8 inches anteriorly, 4.5 inches posteriorly, and 4.5 inches laterally. While shifts of CG of all subjects were found to follow a definite pattern, the variations between subjects in any one position was sometimes greater than the shift of CG of the group due to any particular motion.

214. Thiberg, Sven, et al. Anatomy for Planners I: List of Literature.

Report 20, The National Swedish Institute for Building Research, Stockholm, Sweden, 123 pages, 1965.

This partially annotated bibliography contains over 900 works on dimensions of the human body and applications of body measurement data to the design of household equipment and workspaces. Reports compiled here come from a number of European countries as well as from the U.S. and cover such subjects as classical and functional anthropometry, standing, sitting and lying postures, reach envelopes, joints, muscles and body frame.

215. Thompson, Dennis, J. D. Barden, N. S. Kirk, D. L. Mitchelson and J. S. Ward. Anthropometry of British Women.

Institute for Consumer Ergonomics, Ltd., University of Technology, Loughborough, Leicestershire, England, 16 pages, 1972.

This paper reports data on five body measurements--height, weight, upward reach, forward reach and elbow height--taken on 7,187 British women between the ages of 18 and 80. Results are presented in tables depicting (1) data in terms of age group--number of subjects in each group, mean value, standard deviation and range of values, and (2) values of a given dimension in terms of percentile distributions. A final table presents the correlation coefficients calculated for each combination of the five measurements with each other one, in terms of age groups.

Data gathered were selected for their relevance to the design of workplaces, furnishing and equipment in the home.

216. Thordsen, Marvin L., K. H. Eberhard Kroemer and Lloyd L. Laubach. Human Force Exertions in Aircraft Control Locations.

AMRL-TR-71-119, Aerospace Medical Research Laboratory, Wright Patterson Air Force Base, O., 77 pages, 16 references, 1972. (AD 740 930)

This report describes experiments designed to measure the maximum forces that subjects can exert at selected hand-operated aircraft control locations. A total of 44 force exertions were measured in six common control locations: stick, throttle, collective, overhead control, panel control and hatch control. The sample was composed of 51 subjects, chiefly students.

Results of the study show that the amount of force depends decidedly on the location of the control and on the directions of force exertion. In all of the locations, smaller forces were generally exerted in directions perpendicular to a line passing from the handle location to the shoulder of the arm used, while larger forces were usually recorded in directions along that line.

This study provides engineering data to aid in the selection and arrangement of manual controls.

217. Thornton, William E., G. W. Hoffler and J. A. Rummel. Anthropometric Changes and Fluid Shifts.

Johnson Space Center Report 09275, Proc. Skylab Life Sciences Symposium, 21 pages, 1974.

The effects of weightlessness on body size, shape, posture and configuration are described in this presentation. "Subjects" were the crewmen of Skylab 4 and data was collected by measurement, photography and direct observations of the astronauts.

Anatomical changes noted and described include straightening of the thoraco-lumbar spine, general decrease in truncal girth and an increase in height. Relaxed posture of the crewman in space resembles that of a quadruped. Body fluids (and consequently center of mass) were found to move significantly toward the head. The authors briefly comment on some implications of zero-g body changes for the design of pressure suits and workspaces.

218. Trotter, M. and G. Gleser. "Trends in Stature of American Whites and Negroes Born Between 1840 and 1924."

American Journal of Physical Anthropology, 9(4):427-40, 10 references, 1951.

In this study, secular trends for height of U.S. white and black males and females were determined by measuring selected long bones of 1,466 cadavers. Data are graphically presented and analyzed. Results showed a relatively constant average stature devoid of trend for all four groups born in the latter half of the 19th century. A slight increase in stature is seen for both male and female blacks between 1895 and 1905 and a significant increase occurs in male stature in individuals born between 1905 and 1924.

The authors conclude that findings from this study refute the theory that stature increases progressively from decade to decade. They suggest, rather, that stature increases by spurts and then levels off until changing conditions induce a new increment.

219. Toulson, P. K. Report on the Anthropometric Survey of RNZAF Aircrew.

Report No. AMU 3/74, Aviation Medicine Unit, Royal New Zealand Air Force, Auckland, New Zealand, 290 pages, 2 references, 1974.

An anthropometric survey of 238 Royal New Zealand Air Force aircrew was undertaken for purposes of improving procurement of flying clothing size ranges from overseas and to provide comparative measurements with allied Air Forces. A total of 62 measurements were taken and a further 17 derived.

Results are detailed in the form of summary statistics, frequency tables and percentile tables. Since there appear to be some discrepancies in the percentile tables, caution should be exercised in using them.

220. U.S. Air Force. "Anthropometry and Biomechanics--Design Note 211B."

In: AFSC Design Handbook, DH 1-3, Aeronautical Systems Division, Wright Patterson Air Force Base, O., 19 pages, 1973.

This paper is a synopsis of practical resource data covering the basics of static and working-position anthropometry, reach dimensions, weight-height measurements, muscle strength, and joint motion. Material is presented in tables and illustrations and recommendations are made for adapting data to variant conditions (i.e., conditions under which strength values should be slightly modified or the effect of package size on lifting capacity).

Values are based on measurements of the Air Force male population and should be of use to engineers and designers of clothing, equipment and workspaces.

221. U.S. Department of Commerce. Body Measurements for the Sizing of Women's Patterns and Apparel.

SD Catalogue No. C13.20/42, U.S. Government Printing Office, Washington, D.C. 20402, 29 pages, 1971.

This document provides standard size classifications, size designations and body measurements for the consistent sizing of women's clothing. Tables cover sizing programs for 45 body measurements from the classification of Junior Petite (beginning at 79 lbs and 58 inches) to Half Sizes (up to 229 lbs) and Misses Talls (to 70.5 inches). Also included are a span chart to facilitate location of a particular body type and size; a grading guide showing differences between given body measurements of consecutive sizes within a classification; and an adjustment table to facilitate compensation for the effect of foundation garments.

222. Vicinus, Joan Haskell. X-Ray Anthropometry of the Hand.

AMRL-TDR-62-111, Aerospace Medical Research Laboratories, Wright Patterson Air Force Base, O., 38 pages, 14 references, 1962. (AD 291 412)

This report presents a comprehensive descriptive summary of the roentgenographic anthropometry of the hand. The 253 subjects chosen for measurement (91% USAF military personnel, 9% USAF civilian personnel) were selected to closely approximate the range and distribution of hand length and breadth dimensions of the Air Force population as a whole.

Summary statistics for 24 lengths and 20 breadths for both the left and right hands are presented. Also included in this report are complete intercorrelation matrices for both hands indicating the degree of interrelationship among the 44 dimensions.

Analysis of the data indicates that, in general, the right hand tends to be longer and broader than the left with the right hand showing slightly greater variability in length and less variability in breadth than the left.

Roentgenographic measuring techniques are described and illustrated.

223. Von Masaru, Mori and Torao Yamamoto, "Die Massenanteile der Einzelnen Korperabschitte der Japaner" (in German).

Acta Anatomy, 37(4)385-388, 1959

The weights of segments from 3 male and 3 female Japanese cadavers are reported in kilograms and as a percentage of total body weight.

224. Walker, Leon B., Jr., Edward H. Harris, and Uwe R. Pointius. Mass, Volume, Center of Mass and Mass Moment of Inertia of Head and Head and Neck of the Human Body.

Final Report to Department of Navy Contract No. N00014-69-A-0248-0001, 26 pages, 13 references, 1973.

The mass, volume, center of mass and mass moment of inertia of the head and neck and the head were determined for twenty human male cadavers. Procedures for obtaining anthropometric values and anatomical landmarks by external measurements and by use of x-ray procedures are described. Uniform planes for the separation of the head and neck from the torso and separation of the head from the neck were established and are described in detail. The values of the physical properties of the head and neck and the head are tabulated and compared to data reported in previous studies.

225. Wasserman, D. E., T. Germann, D. V. Goulding, and F. Pizzo. An Instrument for Testing Isometric Strength and Endurance.

HEW Publication No. NIOSH 74-109, U.S. Department of Health, Education, and Welfare, National Institute for Occupational Safety and Health, Division of Laboratories and Criteria Development, Cincinnati, O., 28 pages, 14 references, 1974.

This paper describes an instrumentation system consisting of an in-house designed apparatus and commercially available instrumentation to assess human static muscular strength and muscular endurance. No attempt is made to report the results of data obtained utilizing this system.

The value of this paper lies in the description of the newly developed instrument for testing muscular strength and endurance, a relatively simple device which could be constructed by NASA engineers if the need arises.

226. White, Robert M. Anthropometry of Army Aviators.

TR EP-150, Environmental Protection Research Division, Quartermaster Research and Engineering Center, Natick, Mass., 109 pages, 4 references, 1961. (AD 263 357)

Some 40 body measurements, taken from 500 flyers, have been analyzed and are presented here in the form of percentile distributions and 82 bivariate charts. The sample population represented 10% of the total Army aviator population.

Presentation of the data is aimed at designers of flight clothing and personal protective gear.

227. White, Robert M. Anthropometric Survey of the Armed Forces of the Republic of Vietnam.

U.S. Army Natick Laboratories, Natick, Mass., 66 pages, 13 references, 1964.
(AD 458 864)

Fifty-one body measurements were made on 2,129 men of the South Vietnamese Army, Navy, Marine Corps and Air Force. The anthropometric data have been analyzed and presented in the form of statistical values.

It was found that the 50th percentile value for the stature of Vietnamese military personnel is equivalent to the 2nd percentile value for U.S. soldiers, while the 50th percentile value for the weight of Vietnamese is less than the 1st percentile value for U.S. soldiers. The average Vietnamese is about five inches shorter in stature and 43 pounds lighter in weight than the average U.S. soldier.

228. White, Robert M. Anthropometric Survey of the Royal Thai Armed Forces.

U.S. Army Natick Laboratories, Natick, Mass., 62 pages, 12 references, 1964.

A total series of 2,950 military personnel of Thailand was anthropometrically measured. Included in the sample were 2,010 men of the Royal Thai Army, 610 Marines and 330 Air Force men. Fifty-two body measurements were made on each individual. Results are presented here in the form of summary statistics and percentile tables.

It was found that the average height and weight of Thai military personnel were equivalent to the 5th percentile values of height and weight for United States soldiers. The Thai soldier is about four inches shorter in stature and 30 pounds lighter than the average U.S. soldier.

229. White, Robert M. Reference Anthropometry of the Arctic-Equipped Soldier.

TR EPT-2, Pioneering Research Division, U.S. Army Natick Laboratories, Natick, Mass., 23 pages, 11 references, 1964. (AD 449 483)

Data are presented on body dimensions for the size range of the Army population dressed in the Army Arctic clothing ensemble. Eleven soldiers, representing the 5th, 50th and 95th percentiles in stature and weight, were subjects of the study. Sixty measurements were taken on each subject, both while nude and while wearing full Arctic gear. Data are presented in tables showing dimensions of nude and clothed subjects and the differences between them for all three percentile groups.

Purpose of this study was to aid designers of equipment and workspaces to be used in cold weather conditions since Arctic clothing significantly increases the bulk of the operator and the space he occupies.

230. White, Robert M. and Edmund Churchill. The Body Size of Soldiers: U.S. Army Anthropometry-1966.

TR 72-51-CE, U.S. Army Natick Laboratories, Natick, Mass. 01760, 326 pages, 35 references, 1966. (AD 743 465)

An anthropometric survey was conducted on a sample of 6,682 Army men including basic trainees, infantrymen, armored crewmen and aviation personnel. Seventy body measurements were taken on each subject and the resulting data presented in summary statistics, percentile table, bivariate tables and frequency distribution tables. Data is also categorized and compared according to age, geographical origin, Army service category, national extraction and education background of subjects. Changes in body size of Army men between 1946 and 1966 are discussed and Army data are compared with anthropometric data from other services.

231. Whitley, J. D. "The Influence of Static and Dynamic Training on Angular Strength Performance."

Ergonomics, 10(3):305-310, 5 references, 1967.

Three groups of subjects were involved in a ten-week training program designed to increase arm strength. There were 26 college students in each group; those in the static and dynamic exercise groups exercised twice weekly while the control group remained unexercised. Pre- and post-training static strength scores were obtained at six equidistant points in the middle one-third of the 180 range of movement of the fully extended right arm in the forward horizontal plane.

The strength increases for both static and dynamic training were significant; however, this did not obtain for the control group. The results of an analysis of covariance show that the strength gain associated with static training is significantly greater than that following dynamic training. The significant strength increases resulting from both programs were evenly distributed over the angular range investigated.

232. Williams, Marian and Leon Stutzman. "Strength Variation Through the Range of Joint Motion."

The Physical Therapy Review, 39(3):145-152, 11 references, 1959.

This report is based on studies of forces produced by maximum voluntary isometric muscle contraction by 10 college men, 10 college women and 20 sixth-grade children. Tests were made on the larger joints of the limbs (knees, elbows, shoulders, and hips) at intervals through the range of motion. Results are described and graphically presented.

Chief among the conclusions suggested by the various curve patterns produced by recording exertions through the range of joint motion is that in manual resistive exercise, pressure should not always be increased in the middle third of the range as commonly thought; in fact, the authors conclude, this pattern of strength variation appears to be the exception rather than the rule and holds true only for elbow flexion, knee extension and shoulder adduction.

233. Yanagisawa, Sumiko. About Japanese Physique and Body Girth (in Japanese).

Department of Home Economics, Ochanomizu Institute, Women's University, Bunkyo-Ku, Tokyo, Japan, 16 pages, 1974.

A two-phase anthropometric study of Japanese civilians was conducted by the Japanese textile industry for purposes of improving the sizing of ready-made clothing. The first phase took place in 1967-68; forty-one variables were measured on 30,000 males and females between the ages of four and 29. In the second phase of the research (1972-73) 37 measurements were taken on 9,000 men and women aged 25-65. In general, the women were housewives and the men were laborers. Resulting summary statistics are tabulated.

Upon analysis of the data, it was found that males between the ages of 12 and 16 are generally 10 centimeters taller than comparable males 20 years ago. For females the increase averages 8 centimeters. For both males and females between 30 and 50, the average height was found to be 1.5 centimeters higher than 20 years ago.

Younger people (through high school age) were more slender than the average while middle-aged and older persons, especially women, showed a tendency to be more heavy set.

234. Yanagisawa, Sumiko and Shiro Kondo. "Modernization of Physical Features of the Japanese with Special Reference to Leg Length and Head Form."

Journal of Human Ergology, 2:97-108, 11 references, 1973.

This paper presents data on secular trends in Japanese physical features showing that modern Japanese give evidence of an accelerated growth of leg length in proportion to stature and a rapidly accelerated trend toward brachycephaly (increase of the ratio of head breadth to head length). Anthropometrical research conducted in 1966-72 on 17,585 male and 17,952 female Japanese aged 5 to 59 years revealed that the mean lower extremity length grows faster in relation to its adult value than stature, the adolescent growth spurt of the former preceding that of the latter by about one year. Growth of both portions of the body occurs earlier in girls than in boys.

Measurements of the skull dimensions of 1,585 adult Japanese women in 1956-57 showed that the cephalic index or ratio of head breadth to head length was, on the average, 85.9, 84.5, 83.5, and 83.0 for age 20-29, 30-39, 40-49, and 50-59 years, respectively.

235. Yokohori, E. Anthropometry of JASDF Personnel and Its Application for Human Engineering (in Japanese).

Aeromedical Laboratory, Japanese Air Self Defense Force, Tachikawa Air Base, Tokyo, Japan, 198 pages, 1972.

The major portions of this book are devoted to reporting the results of anthropometric measurements of 1,176 pilots and navigators of the Japanese Air Force. One hundred and eight dimensions were measured and data are given in summary statistics and percentile tables.

236. Zeigen, Robert S., Milton Alexander and Edmund Churchill. A Head Circumference Sizing System for Helmet Design.

WADD TR 60-631, Wright Air Development Division, Wright Patterson Air Force Base, O., 97 pages, 23 references, 1960. (AD 251 939)

Authors describe a system for the sizing and design of rigid and semi-rigid helmets based on a single key dimension--head circumference. Anthropometric data, largely obtained in the 1950 survey of 4,063 Air Force flying personnel, were analyzed and three sizing programs were developed: a six-size program for helmets based on mean values; a three-size program for helmets based on mean values; and a six-size program for helmet liners. Also developed were headforms to concretely interpret data in all three sizing programs for the designer.

This report includes an account of the historical development of sizing systems and programs in the Air Force; a detailed statement covering the design rationale and statistical concepts employed; comprehensive tables needed by the designer for all sizing programs discussed; a description of sculpting techniques and problems, and an account of preliminary validation tests and results.

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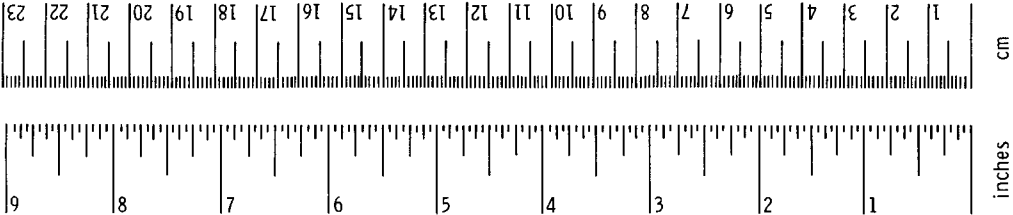
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METRIC CONVERSION FACTORS

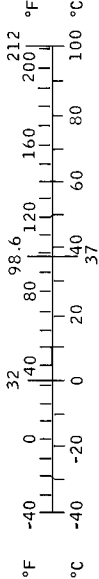
Approximate conversions to metric measures

Symbol	When you know	Multiply by	To find	Symbol
LENGTH				
in.	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
AREA				
in ²	square inches	6.5	square centimeters	cm ²
ft ²	square feet	0.09	square meters	m ²
yd ²	square yards	0.8	square meters	m ²
mi ²	square miles	2.6	square kilometers	km ²
	acres	0.4	hectares	ha
MASS (WEIGHT)				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
VOLUME				
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft ³	cubic feet	0.03	cubic meters	m ³
yd ³	cubic yards	0.76	cubic meters	m ³
TEMPERATURE (EXACT)				
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate conversions from metric measures

Symbol	When you know	Multiply by	To find	Symbol
LENGTH				
mm	millimeters	0.04	inches	in.
cm	centimeters	0.4	inches	in.
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
AREA				
cm ²	square centimeters	0.16	square inches	in ²
m ²	square meters	1.2	square yards	yd ²
km ²	square kilometers	0.4	square miles	mi ²
ha	hectares (10 000 m ²)	2.5	acres	
MASS (WEIGHT)				
g	grams	0.036	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
VOLUME				
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m ³	cubic meters	35	cubic feet	ft ³
m ³	cubic meters	1.3	cubic yards	yd ³
TEMPERATURE (EXACT)				
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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15. Supplementary Notes As an aid to the reader, where necessary the original units of measure have been converted to the equivalent value in the Système International d'Unités (SI). The SI units are written first, and original units are written parenthetically thereafter. The physiological pressure unit used, mm Hg, has not been supplemented with an SI equivalent because of its universal usage in the biomedical field.					
16. Abstract This three-volume publication brings together a large mass of anthropometric data which define the physical size, mass distribution properties, and dynamic capabilities of U.S. and selected foreign adult populations. Aimed specifically to meet the needs of design engineers engaged in the design and execution of clothing, equipment, and workspaces for the NASA Space Shuttle Program, the book is also designed to be of use to human engineers in a wide variety of fields. It is not only a comprehensive source of specific anthropometric information but also a guide to the effective applications of such data. Subjects covered in Volume I include physical changes in the zero-g environment, variability in body size, mass distribution properties of the human body, arm and leg reach, joint motion, strength, sizing and design of clothing and workspaces, and statistical guidelines. Material presented includes such unpublished anthropometric data measured under one-g and zero-g conditions. Also included are 1985 body size projections and actual cutouts of quarter-scale two-dimensional manikins for use by designers. Volume II contains data resulting from surveys of 61 military and civilian populations of both sexes from the U.S., Europe, and Asia. Some 295 measured variables are defined and illustrated. Volume III is an annotated bibliography covering a broad spectrum of topics relevant to applied physical anthropology with emphasis on anthropometry and its applications in sizing and design.					
17. Key Words (Suggested by Author(s)) Height Biomechanics Space Flight Feeding Posture Anthropometry Statistical Analysis Surveys Weightlessness Gravitational Effects Exercise Body Measurement Dimensional Measurement Body Size Body Composition Equipment Specifications Variations Spacecraft Design Human Factors Engineering Body Weight Muscular Strength				18. Distribution Statement STAR Subject Category: 54 (Man/System Technology and Life Support)	
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