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# AN ANNOTATED BIBLIOGRAPHY OF UNITED STATES AIR FORCE APPLIED PHYSICAL ANTHROPOLOGY JANUARY 1946 TO JULY 1976

*AEROSPACE MEDICAL RESEARCH LABORATORY*

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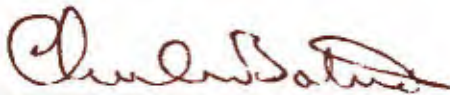
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AMRL-TR-76-58

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This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER



CHARLES BATES, JR.  
Chief  
Human Engineering Division  
Aerospace Medical Research Laboratory

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report contains the titles, authors, publication/source information, and the abstracts of 153 technical reports and articles published by Crew Station Integration Branch, Anthropology Section of the Aerospace Medical Research Laboratory between January 1946 and July 1976. It is a detailed document of the scope of the effort of the Air Force in the field of applied physical anthropology to provide the information on human body size and biomechanical characteristics of Air Force personnel required for the development and		

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evaluation of Air Force systems, personal-protective equipment and clothing. Work in the following areas is described:

Sizing and designing of personal equipment

Body supports

Comfort

Controls

Engineering anthropometry

Body typology

Body forms

Body composition

Anatomy

Anthropomorphic dummies

Anthropometry

Biomechanics

Body composition

Body forms

Body sizes

Center of gravity (humans)

Cockpit geometry

Fit-tests

Helmets

Lifting, pushing, pulling

Man models

Mass distribution (humans)

Mobility

Muscle strength

Oxygen masks

Personal-protective equipment

Physical anthropology

Pressure suits

Range of motion

Reach capability

Seat design

Sizing systems (garments)

Somatotyping

Workstation design

<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
TSEAA-670-9 May 1947 ATI 139 061	Contoured Seat for the Top of an Experimental Rigid Dinghy Box	Hertzberg, H.T.E.

ABSTRACT: The purpose of this paper is to report the adaptation of the rigid dinghy box to contoured seating purposes, and to present metric data on the actual seating surface recommended. This contoured seat should provide the average pilot with both a high degree of seat comfort and with a reasonable ability to extend his legs without undue discomfort. Although several sizes of contoured seats would be necessary to fit all Air Force personnel, the experimental average size described should adequately support the great majority of pilots.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
MCREXD-670-9D June 1949 ATI 67 990	Contoured Seat for Top of an Experimental Rigid Dinghy Box, Report No. 2	Hertzberg, H.T.E.

ABSTRACT: Purpose of this report is to describe some changes in the contour of the original rigid seating surface. These changes were aimed at increasing comfort and reducing the possibility of injury during ejection. Changes consisted of including a groove for the coccyx, moving the position of the lowest point of the seat 1-1/2 inches rearward, and increasing the curvature of certain contour lines. The latter two changes were recommended in order to keep the buttocks more nearly in line with the spinal column during ejection.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
TSEAA-695-58C February 1946 AD 50 569	Principles of Cockpit Seating	Patt, D.I., F.E. Randall, & L.F. Griffis

ABSTRACT: This report presents a study of seating requirements for the pilot position in military aircraft. It is one of a series committed to the determination of the fundamental seat and position requirements of flying personnel in the various crew positions in military aircraft. Ninety-five bomber pilots were used as subjects in these experiments. The fundamental requirements of pilot seating in aircraft were determined

and were found to be dependent upon cockpit level (vertical distance from horizontal line of vision to level of heel rest) and the type of manual control mechanism used (wheel or stick). Comfort requirements have been determined to be dependent upon the same factors, and also upon seat angulation, differential support of the body over the seat contour and the positioning of the rudder pedals and control column with respect to the seat.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
MCREXD-695-71D March 1956 ATI 34 088	A Prone Position Bed for Pilots	Colgan, J.W., & H.T.E. Hertzberg

ABSTRACT: This report describes the development of a prone position bed for pilots, and the results of comfort tests thereof. This bed consists of specially-shaped sides to which a length of nylon netting is affixed. Special controls, foot rests, net tension adjusting cams for abdominal support, chin rest and head support are required as adjuncts to the bed proper. Comfort tests of the bed were conducted with a series of 19 subjects who represented over 95% of USAF personnel in both stature and weight. The bed was adjusted to each subject for utmost comfort. The major adjustments were for stature, abdominal support and for arm position on the controls.

Eighteen subjects lay on the prone position bed for eight consecutive hours each, or longer, and one subject lay four hours. After formal tests were completed, two members of the test team lay on the bed for 12 hours each.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
TSEAA-695-73 December 1946 (Not available from DDC)	Angular Fields of View Through the A-1 Gunsight in the P-80 Cockpit Modified for Ejection	Hertzberg, H.T.E.

ABSTRACT: This report presents the results of a study of the angular field of view in the P-80 cockpit at specified eye-to-pivot distances. Installation of the ejection seat in this aircraft forced the lengthening of cockpits. As a step in providing optimal gun sight placement, the Armament Laboratory requested a study of the angular fields of view available to the pilot at specified eye-to-sight pivot distances 30, 35, 40, 45, and 50 inches.

Four representative pilots wearing standard equipment were employed in measuring the angular fields of view. Their average angular fields of view were found to range from 10.2° vertically and 22° laterally at the 30-inch distance. The only important factors limiting the field of view were the width of cockpit and canopy, and the size of the crash helmet. Other variables such as personal equipment and body size were found to be of no importance in limiting their fields.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
MCREXD-695-80 November 1948	Inhabited Wing Tip Turret	Hertzberg, H.T.E.

ABSTRACT: Purpose of this report was to describe some subjective impressions and objective measurements observed during flight in the inhabited turret installed on the right wing of a B-17 aircraft (a project sponsored by Armament Laboratory). Eight representatives of the Aero Medical Laboratory flew in this turret. Their opinions were unanimous regarding the following subject sensations:

a. The location was livable and comfortable from the physiological standpoint, with no sense of nausea or uneasiness from the most violent maneuvers.

b. Visibility was greatly superior to that of any other situation.

Measurements showed that the highest vertical accelerations the pilot could produce in the wing tip turret by means of the most violent maneuvers were of the order of only plus 4g, while ordinary maneuvers produced only plus 2g. In landing, an instantaneous value of plus 8g was recorded. These forces, however, are not unique to the wing tip position and are easily tolerable.

Certain minor sources of discomfort were found including high noise level which interfered considerably with intercommunication, and also high temperature during taxiing in the hot summer sun. Ventilation and temperature were satisfactory during flight.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
MCREXD-695-82 April 1949 AD 70 599	Comfort Tests of the Pulsating Seat Cushion and Lumbar Pad	Hertzberg, H.T.E.

ABSTRACT: The tests were conducted using 21 subjects who represented approximately 88% of Air Force personnel in weight and 95% in stature. The period of sitting varied from four hours, 55 minutes to eight hours, with an average of six hours, 45 minutes. One group of subjects sat on the non-pulsating cushion an average of two hours, 40 minutes before starting the pulsations. The second group had the cushion pulsating through the test. Apparently the latter group was able to sit somewhat longer under these conditions--approximately four hours on the average--before reaching the peak of discomfort, although this cannot be considered definitely established. Subjects periodically expressed their degree of discomfort on a five step scale ("absent, mild, moderate, severe, unbearable").

Test results indicate that this cushion does help to relieve buttock discomfort, but does not eliminate it.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
MCREXD-720-143 October 1949 ATI 122 733	Hammock for the B-36 Airplane	Hertzberg, H.T.E., & G.S. Daniels

ABSTRACT: This report describes a rapidly demountable net sleeping hammock for intermittent use by the stand-by crew in the forward compartment of the B-36 airplane.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AAF-TR-5501 June 1946 ATI 25 419	Human Body Size in Military Aircraft and Personal Equipment	Randall, F.E., A. Damon, R.S. Benton, & D.I. Patt

ABSTRACT: This report deals with the relation of human body size to military aircraft and equipment. It contains the necessary data and instructional material to guide the designers of aircraft and associated flying equipment in the proper use of anthropometry, as it applies to AAF flying personnel. The functional man is fully described and the spatial requirements of his personal equipment are evaluated. Finally, the complete functional man is considered in his air crew position and as an integral part of the functional aircraft.

<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
MCREXD-45341-4-5 March 1950 ATI 74 410	The Center of Gravity of a Fully Loaded F-86 Ejection Seat in the Ejection Position	Hertzberg, H.T.E., & G.S. Daniels

ABSTRACT: Purpose of the study was to determine the center of gravity of the F-86 Ejection Seat in ejection position when loaded with a pilot wearing full flying equipment. The c.g. of the seat was measured by suspension in two positions under full load. It was shown that the c.g. varies for each individual according to size, weight, and body build, and also for the position of the subject on the seat. Thus the c.g. of an individual may be thought of as an area rather than a point. The average c.g. of nine subjects was located at a point 13-3/16 inches from the back of the seat and 15-7/8 inches from the bottom of the seat pan. For the lighter than average men in this series the average c.g. was located approximately 1/4 inch aft and 1/4 inch below that point. The c.g. of the loaded seat thus travels roughly 7/8 inch along a line whose angle is approximately 30° from the seat pan.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
Am. Jour. Phys. Anthropol. 6:3, 363-371, September 1948	Post War Anthropometry in the Air Force	Hertzberg, H.T.E.

ABSTRACT: A resume of activities current in 1948 in the Anthropology Branch.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
Am. Jour. Phys. Anthropol. 10:2, 201-208 June 1952	Air Force Anthropology in 1950	Hertzberg, H.T.E., & G.S. Daniels

ABSTRACT: This paper presents an account of research underway, emphasizing its breadth and diversity.

<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
Am. Jour. Phys. Anthropol. <u>10:2</u> , 209-215 June 1952	Applied Anthropometry of the Hand	Daniels, G.S., & H.T.E. Hertzberg

ABSTRACT: This paper describes briefly the development of the stick grip used in controlling aircraft, and the research on hand shape that underlies a new design of stick grip.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
TN WCRD 52-81 September 1952 AD 99 784	Review of Escape Hatch Sizes for Bailout and Ditching	White, C.B., P.J. Johnson, & H.T.E. Hertzberg

ABSTRACT: The purpose of this study was to review war time specifications of escape hatches in terms of current and experimental flying equipment. Seven subjects ranging in height, weight, and shoulder width from the 5th percentile to the 95th percentile of Air Force flying personnel (1950 Survey) were used in most of these tests. Three combinations of clothing and equipment were involved. The mock-up for the tests consisted of a plywood panel having slats. The panel could be positioned in the horizontal, vertical or any intermediate plane to simulate an escape hatch in any portion of the aircraft, while the opening could be adjusted to any desirable size from 17 inches to 36 inches square. These tests demonstrated that the present standard sizes of 20 by 31 inches for the side hatch and 20 by 29 inches for the bottom hatch were adequate for use with either the current equipment or the newer experimental clothing providing no tunnel is involved, or the access area is not obstructed. Furthermore, the standard size of the top hatch should be increased to 22 by 22 inches and there should be a step or ledge not more than 45 inches below the lowest edge of the hatch to give additional leverage to shorter crew members.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
WADC TR 52-321 September 1954 AD 47 953	Anthropometry of Flying Personnel - 1950	Hertzberg, H.T.E., G.S. Daniels, & E. Churchill

ABSTRACT: Body size data for 132 measurements of over 4,000 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 based on flight duties.

A Glossary and Bibliography are included.

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

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
TN WCRD 53-7 December 1952 AD 10 203	The "Average Man"?	Daniels, G.S

ABSTRACT: The tendency to think in terms of the "average man" is a pitfall into which many persons blunder when attempting to apply human body size data to design problems. Actually it is virtually impossible to find an "average man" in the Air Force population. This is not because of any unique traits of this group of men, but because of the great variability of body dimensions which is characteristic to all men. It is the intent of this Technical Note to point out and explain some of the factors that lead to the difficulties arising from the use of "average" dimensions and to indicate to some extent how they may be avoided.

The data on which this Technical Note is based are the results of the Air Force Anthropometric Survey of 1950. There is, however, every reason to suppose that conclusions similar to those reported here would have been reached if the same type of analysis had been applied to body size data based on almost any group of people.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
WADC TR 53-12 July 1953 AD 20 542	Anthropometry of WAF Basic Trainees	Daniels, G.S., H.C. Myers, & S. Worrall

ABSTRACT: 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. In general, these statistics are reported in both the metric and English values.

A complete description of the anthropometric techniques used is presented.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
WADC TR 53-14 May 1953 AD 16 748	Nomographs of Head Measurements	Churchill, E., & G.S. Daniels

ABSTRACT: 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 12 head dimensions based on known values of head length and head breadth, and head breadth and head circumference.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
WADC TR 53-49 July 1953 AD 20 717	Anthropometry of Male Basic Trainees	Daniels, G.S., H.C. Myers, & E. Churchill

ABSTRACT: 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. In general, the statistics are reported in both the metric and English values.

A complete description of the anthropometric techniques used is presented.

<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
WADC TR 53-53 March 1953 AD 13 206	Development of a Workspace Measuring Device	Dempsey, C.A.

ABSTRACT: This technical report describes a Workspace Measuring Device which was developed to determine the maximum, minimum and optimum space requirements of Air Force pilots when seated in the cockpit situation; and to simulate in the Laboratory existing or proposed cockpit designs with an eye to proper space utilization.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
WADC TR 54-6 April 1954 AD 30 282	Ground Study of the Non-Ejection Methods of Escape from B-47B Aircraft	Morrison, N.K., & L.A. Schafer

ABSTRACT: This report covers Phase 1, a Ground Study of the non-ejection methods of escape from B-47B aircraft. Because the cabin space available to the crew members is so limited, it was necessary to make a thorough investigation of those body positions and movements at the disposal of the crew when evacuating the aircraft. This study, done at the Wright-Patterson Air Force Base, led to the establishment of optimum procedures to be followed by each man when leaving his station and reaching the possible escape exits, and the most feasible body positions for leaving the aircraft.

The personal equipment worn by each subject during these tests included both winter and summer flying clothing. Each procedure was performed with and without the A-1 survival kit.

Time studies covered crew escape through the ventral hatch, with and without the use of an escape bracket, and through the crawlway to the bomb bay. Eight crews participated in the ventral hatch tests and six crews in the bomb bay tests. Ground studies of egress through the navigator's ditching hatch and canopy were limited to the timing of individuals making personal leads disconnects and standing at their stations. The feasibility of using these exits will have to be determined during the Air Study Phase.

Analysis of the data thus accumulated indicates that the optimum method of non-ejection escape from this aircraft is through the central hatch in a feet-first, facing-aft position utilizing the Barto escape bracket. It must be stressed that the data are based on the tests made with the aircraft on the ground and in the absence of factors that would cause a flight emergency necessitating bailout.

<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
WADC TR 54-520 August 1956 AD 110 573	The Anthropometry of Working Positions	Hertzberg, H.T.E., I. Emanuel, & M. Alexander

ABSTRACT: A sample of 40 adult males 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 data gathering.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
WADC TR 54-548 August 1955 AD 81 792	Arm Strength at Selected Degrees of Elbow Flexion	Hunsicker, P.A.

ABSTRACT: A selected summary of the strength testing literature forms the first part of this study. This is followed by a listing of the modifications that had to be made on the Kinematic Muscle Study machine as a result of exploratory testing. The major portion of the investigation is concerned with the results of testing 55 young men on 60 arm strength tests in the sitting position and 60 in the prone position. Percentile tables and figures depicting arm strength in relation to degrees of elbow flexion are included. Recommendations for further use of the Kinematic Muscle Study machine are offered.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
WADC TR 55-159 July 1955 AD 87 892	Space Requirements of the Seated Operator	Dempster, W.T.

ABSTRACT: The structure of the limb joints and the range and type of their motions were studied on cadaver material, with supplementary work on living subjects, in order to clarify geometric, kinematic and engineering aspects of the limb mechanism. Plans for the construction of manikin joints which showed normal ranges of limb movement were developed from this information. Specifications were also worked out for drafting board manikins which show correct limb ranges for seated postures. Subjects comparable to the model physique of Air Force flying personnel and highly selected small samples of muscular, thin, and rotund builds supplied

information on the range of possible hand and foot movements which was consistent with the seated posture. Maximum dimensions of the work space for seated individuals were determined; a study of the kinematic factors involved permitted 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 moments of inertia. This work was supplemented by data on the distribution of body bulk in the living subjects studied. Applications of the above information to analyses of horizontal push and pull forces in terms of couples permitted an evaluation of the effectiveness of body mass, leverages and support areas.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
WADC TR 56-30 May 1958 AD 155 622	Annotated Bibliography of Applied Physical Anthropology in Human Engineering	Hansen, R., & D.Y. Cornog

ABSTRACT: This volume contains condensations of 121 reports in the field of Applied Physical Anthropology. A majority of the annotations are grouped under three headings: Anthropometry, Biomechanics and Comfort; a few are included in a general group. Working data and important illustrations 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. Two appendices containing relevant commentary on Seating Comfort and Anthropomorphic Dummies, are also included.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
WADC TR 56-364 February 1957 AD 118 003	Linear Distance Changes over Body Joints	Emanuel, I., & J.T. Barter

ABSTRACT: Linear distance changes over the body surface resulting from various joint movements were studied on a series of 30 young men. The following joints and joint complexes were studied: head and neck, shoulder, elbow, wrist, fingers, trunk, hip, knee, and ankle. Summary statistics and design values are presented for 48 linear distance changes measured over these joints.

While there are usually definite and significant changes in bodily dimensions resulting from joint movements, these changes are generally fairly constant

in magnitude. At the same time, the changes are mostly unrelated to body size. The information is designed for application to close-fitting altitude clothing which must provide both physiological protection and body mobility. In addition, these data can serve as a guide for determining easement factors for more commonplace types of clothing.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
WADC TR 56-365 April 1959 AD 130 917	A Height-Weight Sizing System for Flight Clothing	Emanuel, I., M. Alexander, E. Churchill, & B. Truett

ABSTRACT: This report presents a height-weight sizing system for use by designers and fitters of flight clothing. The observations and recommendations reported here are based on a reanalysis of the body size data of the 1950 Anthropometric Survey of Air Force flying personnel.

This reanalysis consisted of selecting pairs of dimensions and correlating these with other dimensions important in clothing design. Among the pairs studied, height and weight have been chosen as basic sizing dimensions. In addition to presenting the methodology used in the present problem, the practical and statistical problems of developing a sizing system are thoroughly discussed. Finally, tables of body dimensional data are presented for several basic size programs (6-size, 8-size, 9-size, and 12-size), since the number of sizes varies with the type of garment. These tables include fitting charts, estimated procurement tariffs, design ranges, mean values for size groups, and bivariate tables for height and weight with size categories marked off for each program. The choice and application of these programs are discussed in detail.

Descriptions of the selected body dimensions are included.

Advantages of the height-weight system include improved fit, fewer alterations, minimal adjustability, and simplified procurement, distribution and fitting procedures.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
WADC TR 56-366 August 1956 AD 97 205	A Statistical Comparison of the Body Typing Methods of Hooton and Sheldon	Dupertuis, C.W., & I. Emanuel

ABSTRACT: Body type component ratings made according to the standards of Hooton and Sheldon were compared in a sample of 500 Air Force flying personnel. Correlation coefficients for the two ratings of the same components are as follows: first component, .82; second component, .83; third component, .86; gynandromorphy, .66; dysplasia, .05. On the average, the Hooton ratings were .51 unit more than the Sheldon ratings for the first component, 1.00 unit less for the second component, and .67 unit more for the third component. For all three primary components identical ratings were given in 33.7% of the cases, while an absolute deviation of one unit occurred in 50.3% of the cases, a deviation of two in 15.5% of the cases, and a deviation of three units occurred in .6% of the cases. Six subjects were given identical body type ratings according to both systems. Regression equations are given for the relationships between the primary components, but the standard errors of estimate are too high to permit accurate equation of body type assessments on the same individual.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
WADC TR 56-367 August 1956 AD 97 206	A Study of Human Weight Lifting Capabilities for Loading Ammunition Into the F-86H Aircraft	Emanuel, I., J.W. Chaffee, & J. Wing

ABSTRACT: The weight lifting ability of a sample of 19 young men was studied. The lifting procedures were standardized and controlled in order to simulate a precise task, that of loading ammunition into the F-86H aircraft. An ammunition case with varying amounts of weight was lifted to platforms one, two, three, four, five, six and 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 performed at the seven foot platform. Suggested maximum weights required for actual lifting tasks are presented. Based on the 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.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
WADC TR 56-404 February 1957 AD 110 548	A Comfort Evaluation of a Form-Fitting High Altitude Helmet	Alexander, M., & H.T.E. Hertzberg

ABSTRACT: 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. Seventy-two subjects were used, of whom 21 were rated military pilots. A number of testing techniques and fabrication requirements for comfort and acceptability are discussed, and their applicability to most forms of headgear, especially those using compressible liner material, is indicated.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
WADC TR 56-458 December 1956 AD 97 216	Body Dimension Changes During Basic Training	Meyers, H.C., G.S. Daniels, E. Churchill, & N.S. Roelke

ABSTRACT: Changes during basic training in the body dimensions of approximately 200 male and a similar number of female airmen were measured. Eight circumferences, weight, and stature were measured weekly during each of the first four weeks and during the eighth and twelfth weeks of training.

The results 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.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
WADC TR 56-459 June 1956 AD 97 217	Bodily Dimensions of the Older Pilot	Fry, E.I., & E. Churchill

ABSTRACT: A comparison of 132 body dimensions on selected groups of older and younger pilots is presented. These groups are compared on their mean values of these dimensions, and more intensively on five percentile distributions of 20 dimensions.

When differences exist between the groups, an explanation has been sought in terms of the physical process of aging, and in selection.

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 Air Force equipment.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
WADC TR 56-599 December 1956 AD 110 589	A Sizing System For High Altitude Gloves	Barter, J.T., & M. Alexander

ABSTRACT: 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 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.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
WADC TR 56-621 June 1957 AD 110 629	Metrical Relations Among Dimensions of the Head and Face	Churchill, E., & B. Truett

ABSTRACT: Correlation data for the head and face dimensions of two groups of USAF personnel are presented. These data extend the useful information about these dimensions into the areas in which two or more dimensions are considered simultaneously. Forty-one dimensions of flying personnel, based on a sample of over 4,000, and six dimensions of WAF trainees, based on a sample of 852, are reported. In addition to a presentation of the data, the report discusses the utility of correlational statistics in the design of personal equipment and describes the procedures used in obtaining these data.

Coefficients of correlation for the 820 pairs of flying personnel data and the 15 pairs of WAF data are given. Multiple correlation coefficients for each dimension and selected pairs of dimensions for the flying personnel

are also given. Regression equations for estimating one dimension from values of another are listed for most pairs of flying personnel dimensions which are at least moderately well correlated. About 70 bivariate frequency tables are presented.

No useful summary of this large body of statistics can be made since it is the individual data which are of importance.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
WADC TR 57-197 April 1957 AD 118 161	WAF Trainee Body Dimensions: A Correlation Matrix	Churchill, E., & K. Bernhardt

ABSTRACT: 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 two thousand multiple correlation coefficients expressing the degree of relationship between each of these dimensions and 36 pairs of them are also given. Regression equations for estimating all other dimensions from specified values of stature, of weight, and of stature and weight together are listed. Values computed from most of these equations are tabulated for the most frequently occurring values of stature, weight, and stature-weight combinations. This correlation material supplements the basic dimensional data given in Anthropometry of WAF Basic Trainees, WADC TR 53-12, and, with these data, provides a basis for the planning and execution of design programs involving the body dimensions of these individuals.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
WADC TR 57-198 April 1957 AD 118 162	Nomograph of the Hand and Its Related Dimensions	Churchill, E., A. Kuby, & G.S. Daniels

ABSTRACT: The design of equipment which must fit closely a part of the users' body calls for a knowledge both of the actual dimensions of this part of the body and the interrelationships among these dimensions.

This report brings together both types of information for the hand. Dimensional data for the hands of both male and female USAF personnel are summarized in tabular and graphic form. Intensities of the interrelationships within each of the two groups of dimensions are given in the form of tables of correlation coefficients. A series of tables supply

estimates of the other dimensions for the appropriate ranges of values of hand length, hand breadth at metacarpale, hand breadth at thumb, and fist circumference.

Nomographic charts are presented for estimating the related dimensions for all likely combinations of values of the hand lengths and breadths for both USAF flying personnel and WAFs.

The basic data used for the men are those obtained from a survey of USAF flying personnel; for women the data are those obtained from a survey of WAF basic trainees. Data obtained from other surveys of military personnel are summarized; these data suggest the applicability of the tables and charts presented here to the design of articles intended for almost any group of USAF personnel.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
WADC TR 57-260 April 1957 AD 118 222	Estimation of the Mass of Body Segments	Barter, J.T.

ABSTRACT: The present study is concerned with the reanalysis of the data concerning the mass of body segments published in WADC TR 55-159, Space Requirements of the Seated Operator, Dempster, 1955, and in The Center of Gravity of the Human Body as Related to the Equipment of the German Infantry, Braune and Fischer, 1889.

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.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
WADC TN 57-311 August 1957 AD 131 028	A Statistical Evaluation of Joint Range Data	Barter, J.T., I. Emanuel, & B. Truett

ABSTRACT: This study reanalyzes the data concerning the range of motion of human body joints published in WADC TR 55-159, Space Requirements of the Seated Operator, by W. T. Dempster. The reanalysis is intended to present the information in a form more applicable to Air Force design problems. An analysis of variance of 43 joint movements for four subgroups originally selected on the basis of physique revealed that 12 body movements (28%) were related to physique. The subgroup statistics were

combined to yield summary statistics for the total sample of 39 young men. Design ranges were derived from these total group values. Descriptions and illustrations of joint movements are included.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
WADC TR 57-432 July 1957 AD 130 912	Height-Weight Sizing and Fit-Test of a Cutaway G-Suit, Type CSU-3/P	Emanuel, I., & M. Alexander

ABSTRACT: Body size data from the 1950 Air Force Anthropometric Survey have been reanalyzed 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. 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.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
WADC TR 57-586 December 1957 AD 131 089	A Study of Muscle Forces and Fatigue	Hunsicker, P.A.

ABSTRACT: The first phase of the research deals with the strength test results taken on 30 subjects covering 120 strength tests. The subjects were seated in a simulated pilot-seat and six movements were tested. The results are presented in percentile tables and graphic form. The next part of the study involves data on 25 subjects who were tested to determine the amount of strength possible in wrist pronation and wrist supination. The final phase of the research gives information on the strength decrement over a 42-hour period in which the subjects were tested hourly. Several recommendations are offered.

<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
Published in Anthropology in the Armed Services: Research in Environment, Physique, and Social Organization, L. Dupree (Ed.) 1958	Anthropology and Space Research	Hertzberg, H.T.E.

ABSTRACT: This paper discusses the contributions of engineering anthropology in space exploration, pointing out that the brilliant advances into outer space 500 miles up are based on the anthropological developments in oxygen masks, in pressure suits, gloves and helmets, and in other protective equipment. The problem of human survival in an environment offering no oxygen, no water, no atmospheric pressure and no gravity is considered, with a discussion of the means of work output in such conditions. Suggestions are made for preliminary ground research on those problems, which would enlist the aid of academic as well as military anthropologists.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
WADC-TR-58-67 February 1958 AD 150 964	Stereophotogrammetry as an Anthropometric Tool	Hertzberg, H.T.E., C.W. Dupertuis, & I. Emanuel

ABSTRACT: This paper briefly reviews previous biological applications of stereophotogrammetry, and outlines with illustrations the present procedures used to draw human body contours at 1/2 inch intervals. It compares the dimensions derived from plotted profiles with those taken by hand of the subjects themselves. It discusses the utility of stereo data for special anthropometric purposes, and mentions further applications for other biological sciences.

Published in Photogrammetric Engineering, 942-947, December 1957.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
WADC-TR-58-505 March 1959 AD 213 604	Anthropometric Sizing and Fit-Test of the MC-1 Oral- Nasal Oxygen Mask	Emanuel, I., M. Alexander, & E. Churchill

ABSTRACT: A sizing program for oral-nasal oxygen masks, based on total face length and lip length, has been developed through a reanalysis of the 1950 USAF Anthropometric Survey head and face data. Face forms, based on this sizing program, have been constructed for use in the preparation of such masks. The MC-1 Oxygen Mask, and oral-nasal, pressure-demand type mask, has been fabricated in accordance with this sizing system and through the use of these face forms. In the fit-tests, 149 of 150 subjects fit-tested were satisfactorily fitted in their indicated sizes.

This report includes a discussion of the theoretical and practical aspects of the sizing procedure. Design limits and related statistical material and suggested procurement tariffs for each of the six sizes proposed are given. The MC-1 mask is described and the fit-test procedure and results are presented.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
WADC-TR-59-165 April 1959 AD 219 894	A Supine Seat for High-Stress Testing of Primates	Eisen, L., & R.S. Zeigen

ABSTRACT: This study summarizes the design rationale of a supine seat and restraint harness, with surrounding inclosure, for high stress bio-science experiments with a Macaca cynomolgus monkey (Macaca iris). This configuration is intended for test under various abnormal stresses, including high g centrifuge runs. Testing and feeding of the subject in the inclosure will be accomplished to determine his reaction to these stresses. With minimum modification, the Macaque supine seat and restraint harness could accept any primate for ground tests or bioexperiments in space flight. A brief description of an earlier supine test seat and restraint harness for low-stress experiments using a squirrel monkey is included.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
WADD-TR-60-18 January 1960 AD 234 005	The Anthropometry of Body Action	Dempster, W.T.

ABSTRACT: The author discusses the principles of investigating dynamic anthropometry in relation to movement patterns of the human body.

Published in Annals of the New York Acad. of Science, 63:4, 559-585, November 1955.

<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
WADD-TR-60-19 January 1960 AD 233 711	Some Contributions of Applied Physical Anthropology of Human Engineering	Hertzberg, H.T.E.

ABSTRACT: The author defines human engineering as "fitting the machine to the man and keeping him functioning with efficiency, with safety and without discomfort, in any environment," and presents three studies as examples of the contributions that can be made by physical anthropology to human engineering. Under the first example, the author condemns the use of "average data," and summarizes the engineering use of the percentile curve as a tool to improve the sizing of workspace, clothing, or personal-protective equipment. The second example outlines the use of muscle-strength data in improving human safety and ease of machine operation. The third presents an attempt to answer the question, "What happens to the buttocks when you sit on them?" A map of the buttock sitting areas is shown, with a general description of cushions designed according to theoretical and experimental findings.

Published in Annals of the New York Acad. of Science, 63:4, 616-629, November 1955.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
WADD-TR-60-631 December 1960 AD 251 939	A Head Circumference Sizing System for Helmet Design: Including Three-Dimensional Presentation of Anthropometric Data	Zeigen, R.S., M. Alexander, & E. Churchill (Consultants: Emanuel, I., & S. Velsey)

ABSTRACT: A system for the sizing and design of rigid and semi-rigid helmets based on a single key dimension, head circumference, is described. Anthropometric data largely obtained in the 1950 survey of Air Force flying personnel were analyzed. The three sizing programs discussed in terms of tabular data are also referred to in terms of headforms or three-dimensional representations of these data. These programs are a Six-Size Program based on mean values, a Three-Size Program based on mean values, and a Six-Size Program for helmet liner problems.

This report includes an account of the historical development of sizing systems, programs, and resultant headforms in the Air Force; a detailed statement concerning the design rationale and statistical concepts used; comprehensive tables needed by the designer for all sizing programs discussed; a statement as to sculpturing techniques and problems; and a comment on preliminary validation results and on the overall design-material-sizing concept.

Appendices include a glossary of significant terms, descriptions of selected head and face dimensions, a detailed discussion of statistical concepts and formulae referred to in the report and tables of comparative Four- and Six-Size Programs based on the key dimensions: head length, head breadth.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
ASD-TR-61-89 April 1961 AD 258 564	The Anthropometry of the Manual Work Space for the Seated Subject	Dempster, W.T., W.C. Gabel, & W.J.L. Felts

ABSTRACT: The anthropometry of the manual work area was approached by an indirect method using photo records of time exposures showing the motions of a tiny neon lamp as the hand grip. The records of 22 male subjects were analyzed for three sets of motions involving the forward-directed hand and different grip orientations. Techniques were developed for defining the limits of the space within reach relative to the mid-sagittal junction of the seat and chair back. Graphical records of the different hand-range spaces were grouped and compared to bring out variability data, the extent of right-left hand overlap, regions of maximum hand flexibility, mean hand positions, etc. The data have been discussed in relation to the geometry of the more effective hand positions and in relation to practical problems of work space designing.

Published in Am. Jour. Phys. Anthrop. 17:4, 289-317, December 1959.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
ASD-TR-61-90 July 1961 AD 263 715	Dynamic Anthropometry of Working Positions	Hertzberg, H.T.E.

ABSTRACT: This paper provides a review of the principles and procedures of workspace design for engineers. It emphasizes that human body size, anthropometry, and muscle force capability, biomechanics, are both essential for the efficient sizing of equipment. The proper method of workspace design, the "design limits concept," is described, and the fallacy of the "average man" concept is demonstrated. General methods of gathering body size and strength data are outlined, and major information sources noted. The author's ideas on human muscle strength in the weightless state are included.

Published in Hum. Factors Bulletin, 2, 147-155, August 1960.

<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
ASD-TR-61-206 December 1961 AD 280 049	Nylon Net Seat for a Modified RB-57 Aircraft	Hertzberg, H.T.E.

ABSTRACT: A light-weight, adjustable, easily demountable net seat for persons who must operate in cramped quarters is described. Tests lasting for more than a year in a modified RB-57 have shown the seat to be fully satisfactory. Design drawings and photographs of the method of installation are included.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
ASD-TR-61-599 October 1961	Anthropometric Data Presented in Three-Dimensional Forms	Alexander, M., R.S. Zeigen, & I. Emanuel

ABSTRACT: The Anthropology Section, Aeronautical Systems Division, has used new as well as standard approaches in the attempt to translate anthropometric data into three-dimensional forms. Basic anthropometric data must be interpreted for the designer and engineer prior to their application to practical problems. One recognized method of presentation is summing each dimension under its mean, standard deviation and percentiles. This approach has been proved quite acceptable for workspace situations concerned with gross measurements. On the other hand, considerable confusion exists among designers and engineers when it comes to handling anthropometric data for items of close-fitting protective equipment, e.g., pressure suits, oxygen masks and helmets. In the past, various head and body forms have been fabricated to provide the designers with more concrete expressions of anthropometric data. Recent efforts along these lines have led to the development of new three-dimensional forms, some of general applications and others for specific problems. All of the current approaches employ key dimensions chosen to determine size ranges. Items included under this program are (1) a series of faceforms (key dimensions are total face length and lip length), (2) two series of headforms (both using head circumference as the key dimension, and (3) a series of body manikins (based on height and weight). The special set of faceforms has been used to size a new light-weight oxygen mask; the two headform series are in use for the experimental sizing of various helmets; and the body manikins are being fabricated to represent a range of body sizes using a height-weight system for flight clothing. The design rationale on which these forms are based and the difficulties encountered in sculpturing them to dimension are discussed.

Published in Am. Jour. Phys. Anthropol. 19:2, 147-157, June 1961.

<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TDR-62-111 September 1962 AD 291 412	X-Ray Anthropometry of the Hand	Vicinus, J.H.

ABSTRACT: Presented in this report is a comprehensive descriptive summary of the roentgenographic anthropometry of the hand. The 253 subjects chosen for measurement have been selected so as to be representative of the Air Force population in hand length and hand breadth.

Summary statistics for 24 lengths and 20 breadths for both the left and the right hands are presented. Also included in the report are complete intercorrelation matrices for both hands indicating the degree of inter-relationship between 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. The lowest correlations occur in the relationships between length and breadth dimensions, and the highest are to be found within the length dimensions of each of the five digits.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
Tech Memo SEM-TM-63-3 November 1963	Helmet Visor Defog Capabilities and General Evaluation of the G-2C-1 Space Suit Assembly	Middleton, R.H., C.J. Muick, M. Alexander, & F.K. Klemm

ABSTRACT: The purpose of these evaluations is (1) to determine the capability of the Gemini prototype ventilation system to keep the helmet visor from fogging during various abort and/or emergency phases of the Gemini mission; (2) to determine what fogging solution will be adequate to prevent visor fogging in the event the ventilating system is inadequate during emergency orbital conditions; (3) to measure suit volume, body volume of the subject, and dead air space between suit and subject as a means of determining the efficiency of the ventilating system; and (4) to determine growth increments (ballooning) during the inflated state of the suit.

<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TDR-63-36 May 1963 AD 410 451	Moments of Inertia and Centers of Gravity of the Living Human Body	Santschi, W.R., J. DuBois, & C. Omoto

ABSTRACT: A study was conducted to determine the moments of inertia and centers of gravity of a sample of 66 living male subjects representative of the Air Force population in stature and weight. Eight body positions were investigated: Standing; Standing, Arms Over Head; Spread Eagle; Sitting; Sitting, Forearms Down; Sitting, Thighs Elevated; Mercury Configuration; Relaxed (Weightless). The procedure was based upon the compound pendulum having a theoretical accuracy of approximately  $\pm 2$  to  $\pm 8$  per cent depending upon position and axis. Orthogonal axes, defined as the intersections of the sagittal, frontal, and transverse planes through the standing body, were designated as X, Y, and Z. A set of 50 anthropometric dimensions was taken on each subject, as well as photographs of each subject in each position. Results of the study show that the average moment of inertia varied in this sample from 11 pounds in sec.<sup>2</sup> about the Z axis to 152 pounds in sec.<sup>2</sup> about the X axis. Linear regression analysis of moments of inertia vs. stature and weight yielded correlation coefficients ranging between 0.77 and 0.98.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TDR-63-55 June 1963 AD 411 556	Anthropometric Data In Three-Dimensional Form: Development and Fabrication of USAF Height-Weight Manikins	McConville, J.T., M. Alexander, & S.M. Velsey

ABSTRACT: 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 flight equipment with a variety of anthropometric data in three-dimensional form.

In part, the data are based on a reanalysis of the body statistics reported in WADC Technical Report 56-365, A Height-Weight Sizing System For Flight Clothing, with certain changes in the statistical rationale required by either functional or technical factors. The choice and application of the statistical data used are discussed in detail. Information is also given concerning the sculpturing techniques used in the fabrication of the body forms.

Supplementary anthropometric statistics describing the human body in a seated position are presented. These statistics are analyzed in accordance with the Eight-Size Height-Weight sizing system.

<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TDR-63-123 December 1963 AD 600 618	Human Mechanics Four Monographs Abridged	Krogman, W.M., & F.E. Johnston
(1. Center of Gravity of the Human Body		Braune, W., & O. Fischer
2. Theoretical Fundamentals for a Mechanics of Living Bodies		Fischer, O.
3. The Human Motor		Amar, J.
4. Space Requirements of the Seated Operator.)		Dempster, W.T.

ABSTRACT: This report condenses four important monographs in the field of applied human mechanics.

The Center of Gravity in the Human Body is a study of the main center of gravity in the human body and the centers of its several parts. It is based upon the measurement and positional analysis of four frozen adult male cadavers, projected to an x, y, z coordinate system. The basic data are transferred to a living adult male soldier, with and without load, in differing military positions.

Theoretical Fundamentals for a Mechanics of Living Bodies is the analysis of freely movable joint systems ("n-link systems") in the living human body. The aim is (1) to present the kinetics of joint systems, and (2) the analysis of states of motion and equilibrium. Part I presents a three-link joint system and the n-link plane and solid joint system. Part II is an application to the mechanics of the human body and to motion in machines (latter here omitted).

The Human Motor is devoted to the application of principles of mechanics to bodily movements, specifically oriented to work-situations. There are discussions of musclebone kinetics in structure and function; the physiology of fatigue is stressed. Environmental factors are discussed: external, as climate, temperature, altitude, etc.; internal, as heart, lungs, nutrition, etc. Experimental devices to measure energy exchange are given. All data are finally interpreted in terms of actual work performance in tool use, time, and motion, etc.

Space Requirements of the Seated Operator is the analysis of the human body, utilizing osteological material, cadavers, and living subjects, in terms of body links and kinetics, differential tissue relationships, physique differences, and the range of normal variation, carried out for the purpose of more precisely defining the work space required by seated individuals in various tasks. The results consist in the presentation of these requirements for a variety of seated functional postures, as well as detailed plans for the construction of kinetically-correct two- and three-dimensional manikins.

<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AGARDograph No. 73, The MacMillan Company, New York, 1963 AD 421 428	Anthropometric Survey of Turkey, Greece and Italy	Hertzberg, H.T.E., E. Churchill, C.W. Dupertuis, R.M. White, & A. Damon

ABSTRACT: This report describes the planning and organization of the NATO Anthropometric Survey of 1960-61, and presents the tabulated data for 150 body dimensions taken on 3356 military personnel: 915 Turks, 1084 Greeks, and 1357 Italians. Besides body dimensions, the data photographs, skinfold thicknesses and other measures on each subject permitting assessment of body composition. (Taken during the Survey, but omitted from this volume, are data from X-ray photographs of the right hands of 150 Greek and 150 Italian subjects.) The tabulated data include the means, standard deviations, coefficients of variation of 150 body dimensions, as well as selected percentiles of each form from the 1st to the 99th, for each total national sample and subsample. When available, USAF data are presented for comparison. Each dimensional listing is accompanied by a sketch locating the dimension, a photograph illustrating the technique of measurement, and verbal instructions for procedure.

There are chapters, each signed by its own author, presenting team acknowledgements, and introduction to the problem, the technical procedures used, and a summary of the statistical methods employed. A preliminary somatotype study (based on every 10th man) describes the body types encountered, with illustrations of four physical types from each country; and an analysis of skinfold-thickness data presents an estimate of body fat in the sample. A final chapter sketches the history of anthropometric surveys, and outlines the wider practical and scientific uses of anthropometric data. Appendices I and II present plans for the construction of special equipment, and Appendix III briefly outlines plans for future publications on these data.

The volume contains a Table of Contents, an Index of Dimensions, a Visual Index of body dimensions, a Glossary, a Bibliography, and many illustrations.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
Chap. 11, Morgan, et.al., Eds.; <u>Human Engineering Guide to Equipment Design</u> , McGraw Hill Book Co., Inc.; New York, Toronto, London, 1963	Anthropometry	Damon, A., H.W. Stoudt, & R.A. McFarland

ABSTRACT: This 130-page chapter contains extensive anthropometric, muscle-strength, and range-of-motion of body-segment data on numerous United States military populations. Their application to many types of human engineering problems is detailed.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TDR-64-41 May 1964 AD 603 705	Finger Dexterity of the Pressure-Suited Subject	Walk, D.E.

ABSTRACT: This study attempts to establish an objective baseline for evaluating the functional mobility of pressure gloves. The Purdue Pegboard Dexterity Test was employed to measure hand dexterity under three conditions: (1) subjects barehanded, but wearing an unpressurized A/P22S-2 full-pressure suit ensemble; (2) subjects gloved (HAK-3/P-22S-2) and suited, but not pressurized; (3) subjects gloved, suited, and pressurized to 2.5 psi. The Purdue Pegboard Dexterity Test has been found to be a delicate indicator of hand dexterity in the test conditions. The test results show a marked reduction in dexterity even with the gloves and suit uninflated, and an additional loss when gloves and suit are inflated. The degree of loss of dexterity is believed to provide an objective measure whereby one operational aspect of pressure gloves may be evaluated.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TDR-64-59 September 1964 AD 608 269	Reach Capability of the USAF Population. Phase I: The Outer Boundaries of Grasping- Reach Envelopes for the Shirt- Sleeved, Seated Operator	Kennedy, K.W.

ABSTRACT: This report contains descriptions of the outer boundaries of the Minimum, 5th-, 50th-, and 95th-percentile grasping-reach envelopes of seated, shirt-sleeved operators. The two most important are the Minimum and 5th-percentile envelopes. These envelopes have been calculated to permit 99+ percent or 95 percent of the Air Force population, respectively, to reach any point at their boundaries. The report contains a critical resume of previous investigations of arm reach, and a description of the AMRL Grasping-Reach Measuring Device. The data-gathering and statistical procedures are included, and applications of the reach envelopes are

discussed. Horizontal contours representing the outer boundary of the Minimum, 5th-, 50th-, and 95th-percentile grasping-reach envelopes are presented for each 5-inch level beginning at five inches below SRP (Seat Reference Point) and extending to 50 inches above SRP. The minimum envelopes extended from 2.5 inches below SRP to 48 inches above; the 5th-percentile envelope from four inches below SRP to 48.75 inches above. Horizontal distances from SRP to the boundary of each envelope are given at 15° intervals.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TDR-64-66 July 1964 AD 606 039	Height-Weight Sizing of Protective Garments, Based on Japanese Air Self-Defense Force Pilot Data, with Fit-Test Results	Alexander, M., J.T. McConville, J.H. Kramer, & E.A. Fritz

ABSTRACT: This study 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 upon an anthropometric survey of over 200 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 CSU-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 at Hamamatsu and Tachikawa Air Bases, Japan, in April 1963.

The results of the fit-tests served to validate the soundness of the basic survey data and subsequent development of the Height-Weight sizing program.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-64-102 October 1964 AD 608 463	A Mathematical Model of the Human Body	Hanavan, E.P.

ABSTRACT: A mathematical model for predicting the inertial properties of a human body in various positions has been developed. Twenty-five standard anthropometric dimensions are used in the model to predict an individual's center of gravity, moments and products of inertia, principal moments, and principal axes. The validity of the model was tested by comparing its predictions with experimental data from 66 subjects. The center of gravity was generally predicted within 0.7 inches and moments of inertia within 10 percent. The principal vertical axis was found to deviate from the

longitudinal axis of the body by as much as 50 degrees, depending on the body position assumed. A generalized computer program to calculate the inertial properties of a subject in any body position is presented. The inertial properties of five composite subjects in each of 31 body positions is offered as a design guide. IBM 7094 digital computer programs are appended.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-64-110 November 1964 AD 609 863	Moments of Inertia and Centers of Gravity of the Living Human Body Encumbered by a Full-Pressure Suit	DuBois, J., W.R. Santschi, D.M. Walton, C.O. Scott, & F.W. Mazy

ABSTRACT: 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; and three modes of dress; nude, suited-unpressurized, and suited-pressurized, were investigated. The theoretical accuracy of the experimental procedures, based on a compound pendulum, ranged from two to eight percent, depending on body position and axis. The moments of inertia were found to vary significantly between body positions and between nude and suited conditions. Correlation coefficients between the moments of inertia and stature and weight exceeded 0.9. Fifty anthropometric dimensions and frontal and profile photographs were obtained on each subject to serve as the basis for additional biodynamic analyses.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-64-118 November 1964 AD 610 519	The Use of Lines of Nonextension to Improve Mobility in Full-Pressure Suits	Iberall, A.S.

ABSTRACT: An important objective in the development of a full-pressure suit for a human being is to permit the wearer full mobility without interfering with physical capability. Although the human skin is stretched during body motion, there is virtually no stretch along certain lines, here called "lines of nonextension." This investigation was undertaken to determine the efficacy of utilizing lines of nonextension to provide natural mobility and minimal ballooning in full-pressure suits. The program of investigation pursued was: (1) to map out these lines of nonextension, (2) to test whether string elements of high elastic modulus, a connected network, could be laid along these lines of nonextension without providing any constraint

to mobility, (3) to obtain a highly mobile pressure-retaining layer to be constrained by the net, and (4) to construct and demonstrate an entire pressure-retaining garment system that makes use of necessary layers and string elements in a completely connected, netted covering for the body, with minimal constraint to mobility up to five psi. The technique, result, and collateral observations relevant to each of these phases are described. A mobile, pressure-retaining garment was developed by building each structural, functional layer into the composite garment in accordance with the basic design theory.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-65-31 May 1966 AD 638 282	Relationships Between Flexibility, Anthropometry, and the Somatotype of College Men	Laubach, L.L., & J.T. McConville

ABSTRACT: Fourteen flexibility measurements, 63 direct and derived anthropometric measurements, and the somatotype of 63 college men, mean age of 19.0 years, were obtained in order to assess the relationships between flexibility and anthropometric measurements, anthropometric measurements and somatotype, and flexibility and somatotypes. The correlations between the flexibility measurements and the anthropometric measurements were low and mostly insignificant. Body fat, as measured by skinfold calipers, yielded fairly high significant negative correlations with the flexibility measurements. The correlations between the flexibility measurements and somatotype were insignificant. Generally high correlation coefficients were obtained between the anthropometric measurements and somatotypes.

Published in Research Quarterly, 37:2, 241-251, May 1966.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-65-73 December 1965 AD 632 241	The Anthropometry of Common Working Positions	Alexander, M., & C.E. Clauser

ABSTRACT: Twenty-six dimensions of the human body in various working positions (standing, bending, kneeling, squatting, supine and sitting) were obtained by photography or by direct measurement. The purpose of this study was to provide the human engineer with anthropometric data of various missile worker's positions so that more adequate work stations can be designed. Each dimension is defined verbally and graphically; and the 5th, 25th, 50th, 75th and 95th percentiles and other statistical data are presented.

<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-65-74 March 1965 AD 462 062	Anthropometry of Japanese Pilot	Oshima, M., T. Fujimoto, T. Oguro, N. Tobimatsu, T. Mori, I. Tanaka, T. Watanabe, & M. Alexander

ABSTRACT: The results of an anthropometric survey of 239 pilots of the Japanese Air Self-Defense Force are presented. The survey took place in the spring of 1961 at five air bases located throughout Japan. Sixty-two body dimensions were measured on each subject by JASDF flight surgeons. Measurements of the head, face, trunk, arms, and legs were included for the purpose of sizing and designing pressure suits and associated protective gear for use in the F-104J weapon systems program. The percentiles, means, standard deviation, range and coefficient of variation are presented for each body measurement. Comparisons with the 1950 USAF flying population are included. A detailed description is given for each measurement accompanied by explanatory diagrams. A four-size, Height-Weight program for JASDF pilots is presented for use by protective equipment designers.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-65-107 October 1966 AD 674 306	Muscle Strength, Flexibility, and Body Size of Adult Males	Laubach, L.L., & J.T. McConville

ABSTRACT: Four measures of muscle strength, two measures of flexibility, 30 anthropometric measures (both direct and indirect), and the somatotypes of 45 male subjects were obtained and the interrelationships among these variables investigated.

A low but statistically significant correlation was found between hip-flexion strength and the range of motion of hip extension-flexion; however, this was the only strength measurement to correlate significantly with the flexibility measurements. Many statistically significant ( $p = .05$ ) correlations were found between the anthropometric and the strength measurements, but none between the anthropometric and the flexibility measurements. The only somatotype component to correlate significantly with the measures of muscle strength was mesomorphy; the correlations between the somatotype components and the measures of flexibility were insignificant.

Published in Research Quarterly, 37:3, 384-392, October 1966.

<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-65-163 December 1965 AD 630 639	Development of Design Standards for Ground Support Consoles	Kennedy, K.W., & C. Bates, Jr.

ABSTRACT: Experience gained in using a single standardized ground-support console configuration in the WS 131B, Hound Dog, is discussed. Other ground console designs for possible standardization in future systems are described in detail. All designs are derived from a basic sit-stand configuration and will accommodate approximately 95% of the USAF male population and approximately 60% of the USAF female population. Each of the consoles can be made from five standard subassemblies. The suggested standard configurations permit engineering design freedom, yet restrict certain dimensional characteristics of the consoles to assure accommodation to the requirements and capabilities of the operator.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-65-205 December 1965 AD 637 692	Procedure to Assess Energy Expended During a Short-Period Task	Walk, D.E., & E.H. Sasaki

ABSTRACT: A procedure was developed to measure the energy expended in a rowing task completed during a 12-second zero-G parabola. The technique was based on completed expired air samples. The subject's expired air was collected under three conditions: (1) 30 seconds of rest, (2) 12 seconds of rowing, and (3) 15 seconds of recovery. The conditions were repeated 10 times, and the subject's expired air was cumulated separately in three bags to obtain, in essence, a 5-minute collection for rest, a 2-minute collection for work, and a 2-1/2 minute collection for recovery. This procedure was replicated in four environments: laboratory, aircraft 1G level flights, aircraft 2G-1G-2G bank maneuvers, and aircraft 2G-0G-2G parabolic maneuvers. The results showed that the body reacted to a change in physical activity and returned to a state of equilibrium much more quickly than previously reported in the literature. The volumes of expired air, oxygen, and carbon dioxide in each condition (rest, work, and recovery) were similar in the four environments, but the specific effects, if any, of the differential gravity levels were negligible and unsystematic.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-65-216 December 1965 AD 622 443	An Analysis of the Inertial Properties and Performance of the Astronaut Maneuvering System	Tieber, J.A., & R.W. Lindemuth

ABSTRACT: The inertial properties and performance parameters of an Astronaut Maneuvering System are determined by mathematical modeling. The inertial properties of an astronaut in a space suit are determined by modification of an existing mathematical model of the human body to include a mathematical model of a space suit. The space suit model is based on measurements of suited subjects and suit weight regression equations. The inertial properties determined are: (1) location of the system center of mass, (2) moments and products of inertia about axes through the center of mass, (3) the principal moments of inertia, and (4) the orientation of the principal axes. These properties are used in a computer program developed to analyze the performance of the AMS by simulating the operation of the MMU in the system. Performance parameters determined are: linear and angular acceleration, velocity, and displacement, and fuel consumption. Maneuver and propulsion efficiency factors are defined and calculated. The efficiency factors indicate loss of system efficiency due to inertial cross-coupling, misalignment of center of mass and thrust line, and intermittent thruster operation. The efficiency factors are used to compare system performance during various maneuvers.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
Aerospace Medicine, Vol. 36, No. 5, May 1965	Motion Performance of Pressure- suited Subjects Under Zero and Lunar Gravity Conditions	Simons, J.C., D.E. Walk, & C.W. Sears

ABSTRACT: The motions of unsuited and pressure-suited subjects were studied as they performed lunging, egressing and landing tasks during the weightless and lunar gravity maneuvers of a large cabin aircraft. Performance data are presented for various combinations of clothing, gravity and body position conditions. Time and contact data are presented for the egress motion as it is influenced by changes in the exit diameter. Motions of suited subjects generally required 30 per cent more time than corresponding motions of unsuited subjects under both gravity levels. Most motions required 35 per cent more time during zero-G than during lunar-G. No significant differences in egress time were found for four body-position configurations. Five inches of exit clearance improved egress time by six per cent. Accuracy of motion rather than time of motion appeared to be a more sensitive measure of operator performance for the egress task.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-66-17 May 1966 AD 637 764	A Study of One-Handed Lifting	McConville, J.T., & H.T.E. Hertzberg

ABSTRACT: This research is intended to assist in establishing realistic criteria for the size and weight of industrial packages. The problem of such criteria is discussed, numerous important objective and subjective factors that potentially affect human weight-lifting ability are mentioned, the proper approach to the design of industrial loads is pointed out, and additional programs of investigation that would clarify other aspects of the problem are outlined. This study examined the interaction of two variables--(a) the weight and (b) the width--of one-handed symmetrical boxes which a sample of 30 adult males were able to lift from the floor to a table 30 inches high. No carrying was involved in this study. The subject sample was chosen to be a reasonable representation by height and weight of the U.S. Air Force population. All lifts were made with the preferred hand under "ideal" laboratory conditions. The experimental variable, box width, was varied from six to 32 inches. The maximum weight of box that subjects were able to lift varied linearly, but inversely, with the width of the box. From this sample, the maximum weight that 95% of the population would be able to lift--but not necessarily carry--can be expressed by a linear equation:

$$\text{Weight (pounds)} = 60 - \text{width (inches)}.$$

The numerical values of this formula provide a recommended upper limit on the design of industrial or military equipment which must be lifted under ideal conditions. If the expected conditions of use are less than ideal, or if carrying for appreciable distances is likely to be necessary, reasonable reductions in weight, or size, or both should be made by the manufacturer.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-66-27 October 1966 AD 646 716	Aperture Sizes and Depths of Reach for One- and Two-Handed Tasks	Kennedy, K.W., & B.E. Filler

ABSTRACT: 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 the shirt-sleeved and the pressure-suited conditions. In all cases, the vertical dimension of the aperture permits the technicians to maintain simultaneous visual and manual contact with the task area. Data include Depth of Reach, Breadth of Aperture, Vertical Dimension of Aperture, and the distances from the floor from both the lower and the upper edges of these apertures. Different apertures provide for forward or lateral reaches, in the standing or seated position, with one or both arms.

Data are reported in percentiles, including the 5th, 25th, 50th, 75th, and 95th. Ranges, means and standard deviations are given. Recommendations are made regarding the appropriate application of the data to the sizing and location of maintenance accesses.

<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-66-185 December 1966 AD 656 311	Measurements of Muscle Strength	Laubach, L.L., & M. Alexander
(Sec VIII, Metzger and Fritz, Program Coordinators; Integrated Life Support System Study [20-Day Evaluation Program]).		

ABSTRACT: Tests are conducted to define the various problems involved in the maintenance of an acceptable environment, the number of variables concerned with the man-machine concept, the operation, maintenance and evaluation of single units and integrated systems for the support of life in a simulated aerospace mission. The investigation covers primary problems and benefits associated with water recovery, personal hygiene, sanitation, nutrition, instrumentation, atmospheric conditions at various pressures and mixtures, clothing, crew accommodations, waste management and muscle-strength while confined in a chamber simulating an aerospace vehicle, and the facilities and support required to test and evaluate life support systems.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
Am. Jour. Phys. Anthropol., 25:3, 335-336 November 1966	An "Anvil" for Sliding-Caliper Repair	Hertzberg, H.T.E.

ABSTRACT: This note presents working drawings and a photograph of a tool that facilitates immediate repair of sliding calipers damaged during anthropometric surveys.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
Preprints of Scientific Program of AMA, 166-167, April 1967	Maximal Static Force vs. Stress Measurements as Criteria for Establishing Optimal Work Conditions	Kroemer, K.H.E.

ABSTRACT: Differences between static and dynamic usage of muscles and ensuing consequences for arrangements of controls are discussed. Methods of assessment of physical stress of human operators are briefly reviewed.

In a series of experiments, eight male subjects operated cranks and levers (radii 15 and 30 cm) against torques of resistance of two to 6.8 m.kp. During trials of 10 minutes each, the subject performed either 100 or 200 to-and-fro movements, the angles of rotation being 90 or 180 degrees. The

range of travel of the handles was adjusted to a variety of positions within the reach capabilities of the subjects. Experimental conditions judged by the subjects as most agreeable and which, at the same time caused least increases in their pulse rates, were considered to be optimal for the dynamic work performed.

The results obtained indicate that measurements of man's maximal static forces do not provide an adequate basis for the layout of controls which must enable human operators to perform dynamic-submaximal work with the least amount of fatigue and physical stress.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-67-63 May 1967 AD 658 441	Two-Handed Retention on Various Handle Configurations	Garrett, J.W., M. Alexander, & W.G. Bennett

ABSTRACT: This report presents data on the manual grip-retention capability of seated persons. Nine male subjects, grasping experimental ejection actuators located forward of an ejection seat pan, were required to maintain their grasp against force loadings of 50 to 500 pounds. Grip retention at various increments of time to a maximum of 30 seconds are compared for each of the four handles: a T-bar, Twin grips, a standard D-ring and a flexible Gemini-type loop. Test results indicated that the T-bar provides the greatest grip-retention capability. Potential applications of these performance data are discussed.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-67-82 May 1967 AD 751 734	Notes on Anthropometric Technique: Anthropometric Measurements--Right & Left Sides	Laubach, L.L., & J.T. McConville

ABSTRACT: 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 forelimb, in which the dimension measured on the right side was greater. Since data on handedness is lacking we do not know whether this is related to the handedness of the subjects.

Published in Am. Jour. Phys. Anthropol. 26:3, 367-370, May 1967.

<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-67-135 June 1969 AD 716 632	Body Composition in Relation to Muscle Strength and Range of Joint Motion	Laubach, L.L.

ABSTRACT: The data on 27 body composition, anthropometric and physical performance items were obtained from 45 male subjects and the inter-relationships among these measures investigated.

Many statistically significant ( $p = .05$ ) zero-order correlations were found between the muscle strength and the body composition measures, but none between the range of joint motion measures and body composition. The somatotype components correlated much higher with measures of muscle strength when stature was partialled out of the correlation. The resulting correlations among the physical performance items and the body composition measures when body weight was held constant, were generally lower than the same zero-order correlations and first-order partial correlations (stature held constant).

A few (six) significant correlations were found between the range of joint motion and body composition measurements when both stature and body weight were held constant. Multiple regression equations for the prediction of the physical performance items from the anthropometry and body composition measures are listed.

Published in J. of Sports Medicine and Physical Fitness, 9:2, 89-97, June 1969.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-67-180 January 1968 AD 708 118	The Conference on Standardi- zation of Anthropometric Techniques and Terminology	Hertzberg, H.T.E.

ABSTRACT: The conference, attended by anthropologists, engineers, dental and medical researchers, physical educationists and statisticians, took place on 28-30 March 1967 in the Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio. The ultimate purpose was to improve the comparability of anthropometric data from all workers, 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. In this effort, the group selected a list of dimensions (though with dissent on type and number) recommended as a minimum for all human biological surveys; and they chose from previous usage a terminological structure whose form, content and mode of presentation they recommend as standard practice by all anthropometrists. Both official and dissenting lists are presented, and the terminological structure is described, with examples.

Despite solid progress toward a standardized technology encompassing both classical and modern practices, the conference left numerous points of technique or terminology unsettled, some of which are briefly described. Hence future meetings appear necessary, perhaps annually, until such remaining problems can be resolved.

Published in Am. J. Phys. Anthropol., 28:1-16, January 1968.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-67-203 January 1968 AD 670 869	Anthropometry of the Human Ear (A Photogrammetric Study of USAF Flight Personnel)	Alexander, M., & L.L. Laubach

ABSTRACT: A technique was developed which enables precisely specified ear dimensions to be measured directly from PhotoMetric slides. Summary statistics for each of the various ear dimensions are presented for a sample of 500 subjects randomly chosen from a total series of 2236 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. The reliability and objectivity of the technique is discussed. A complete intercorrelation matrix for all variables studied in this research is also shown.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-67-217 August 1971 AD 731 183	An Introduction to Relaxed Hand Anthropometry	Garrett, J.W.

ABSTRACT: Anthropometric data comparing the length of the relaxed hand with the flat, straightened hand are presented. The correlation coefficient between the hand length in the two positions is not high. A forthcoming comprehensive research program on the anthropometry of the hand is revealed.

<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-68-1, March 1971 LC No. 74-74-607818 AD 723 629 (Volume I) AD 723 630 (Volume II)	A Collation of Anthropometry	Garrett, J.W., & K.W. Kennedy

ABSTRACT: Scientists and engineers are faced with the responsibility of comparing anthropometric data from different populations. So far, the labors required to find and identify comparable dimensions have been left to the individual researcher. To relieve him of the burden of this effort, the descriptions of approximately 2000 anthropometric dimensions from 47 sources have been collated and reported in a manner that makes comparisons convenient. Thirty-nine of these sources are primary sources of statistical data. Thirty-six of the latter were published since 1940, and three are soon to be published. Several classic sources of anthropometric technique have also been collated.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-68-24 August 1968 AD 681 457	Clearance and Performance Values for the Bare-Handed and Pressure- Gloved Operator	Garrett, J.W.

ABSTRACT: This study provides the design engineer with clearance and performance values for operators wearing the A/P22S-2 pressure glove. Thirty-six anthropometric and biomechanical measures on the nude hand, gloved and unpressurized, and gloved and pressurized, were taken. The data for each measure on 27 subjects are both summarized for all subjects and reported independently by glove size worn. Possible uses for each of the measures are suggested and specific design factors for these uses are recommended.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-68-61 December 1968 AD 695 470	Ultrasonic Determination of Body Composition	Stouffer, J.R.

ABSTRACT: The objective of this study was to determine the feasibility of using ultrasonic techniques to determine the volume of fat, muscle, and bone tissue of the living body. Ultrasonic equipment, including a mechanical scanning and recording device was used to produce cross-sectional maps of a

live anesthetized hog, three fresh hams, and three human subjects (endomorph, mesomorph and ectomorph). Thirteen 360° cross-sectional scans on the live hog demonstrated the feasibility of using the technique on live animals. Cross sections of the three hams demonstrated the accuracy of estimating the areas and volumes of the three tissue components from ultrasonic scans. The ultrasonic mapping of the human subjects demonstrated that the technique could be used on all parts of the human body and, in addition, provided an indication of the range of values of individuals of diverse body types.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-68-80 July 1968 AD 848 621	Ergonomics in the Design of Office Furniture: A Review of European Literature	Kroemer, K.H.E., & J.C. Robinette

ABSTRACT: This report discusses the European literature on "healthy" sitting postures and, relatedly, of suitable office and shop furniture, especially of chairs. Recommendations by orthopedists, physiologists, and physical anthropologists are summarized and tabulated for the height, shape, and dimensions of the seat surface; for the shape and dimensions of the back rest; and for the height of office desks, as well as for tables and stands to be used with office machines, such as typewriters.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-68-113 December 1968 AD 737 412	World Diversity in Human Body Size and Its Meaning in American Aid Programs	Hertzberg, H.T.E.

ABSTRACT: This brief review shows quite conclusively that our Air Force people (and hence, our population at large) are giants as compared to these other populations. Not only is the large majority of the flying personnel among our Mediterranean and Oriental allies below our 50th percentile in most dimensions, showing that their sizes are different from ours, but also their proportions are different. Hence, smaller sizes of garments which fit us will not necessarily fit all of them adequately. In any case, it is inescapable that reliable anthropometric data on such populations are essential to the effective solution of the vexing and expensive fitting problems associated with clothing and equipment furnished our allies under our aid programs.

Published in OAR Research Review, 7:12, December 1968.

<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-68-143 August 1969 AD 695 040	Push Forces Exerted in Sixty-Five Common Working Positions	Kroemer, K.H.E.

ABSTRACT: Experiments were conducted to measure the maximum isometric horizontal push forces exertable in 65 common working positions. The subjects (45 male college students), while pushing horizontally, either anchored their feet against a footrest or braced themselves against a vertical wall. Means, standard deviations, and 5th percentiles of the forces exerted are reported.

Male operators can exert horizontal static forces of at least 25 kp (55 lb) pushing with one hand, at least 50 kp (110 lb) pushing either with both hands or with the shoulder, and at least 75 kp (165 lb) pushing with the back--provided they anchor their feet or, better, brace themselves against a vertical wall. A vertical push-panel that allows most subjects to exert maximum horizontal force has a rough surface, is 40 cm (16 in) wide, and extends from 50 cm (20 in) above the floor to 125 cm (50 in) above the floor.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-68-144 May 1970 AD 708 741	Problems in Assessing Muscle Strength	Kroemer, K.H.E., & J.M. Howard

ABSTRACT: Muscle strength is typically reported in terms of "maximum." Experimental data illustrate the importance of defining the method of force exertion and of performance evaluation. Contracting the muscles in different ways or selecting different indexes from the same performance record can result in distinct "maximum" strength scores. To facilitate standardization of experimental procedures and comparison of strength data, a check list is proposed.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-68-151 December 1970 AD 725 386	A Computer Program for Calculating Parnell's Anthropometric Phenotype	Laubach, L.L., & M.E. Marshall

ABSTRACT: A specific computer program was written and compiled for the calculation of Parnell's anthropometric phenotype. This computer program is illustrated and discussed. A total of 2420 male subjects from the

1967 U.S. Air Force Anthropometry Survey were phenotyped in this manner. Descriptive statistics for the phenotype distributions are given for the entire sample divided into 5-year age categories.

Published in The Journal of Sports Medicine and Physical Fitness, 10:4, 217-224, December 1970.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-68-164 March 1970	Ground Areas Visible from the Aircraft Cockpit Eye Position: A Method of Evaluation	Kennedy, K.W.

ABSTRACT: The purpose of this research is to develop a realistic and objective method for comparing aircraft in terms of the ground areas visible from their cockpits. The method 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, may be regarded as an index of the visibility from the cockpit. A camera, which produces superimposed pictures from two lenses separated by the average interpupillary distance, is located at the cockpit-design eye position and the photograph obtained shows a panorama of what the pilot could see if he rotated his head from side to side. To illustrate that only part of the terrain beneath the aircraft is visible from the design-eye position, angular coordinates describing the outlines of obstacles to vision are projected to the ground. Through simple trigonometric analysis, the location of the points where these vectors "strike" the ground are calculated relative to ground "0", a point on the ground directly below the aircraft. Once all necessary points are determined and plotted, it is possible to define the areas on the surface of the earth that are visually inaccessible from the cockpit-design eye position.

Published in AGARD Conf. Proc. No. 55, Problems of the Cockpit Environment, Amsterdam, Netherlands, March 1970.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-69-6 August 1969 AD 697 022	Anthropometric Dimensions of Air Force Pressure-Suited Personnel for Workspace and Design Criteria	Alexander, M., J.W. Garrett, & M.P. Flannery

ABSTRACT: 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.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-69-9, 1970 AD 710 593	Human Strength: Terminology, Measurement and Interpretation of Data	Kroemer, K.H.E.

ABSTRACT: Application of strength data to human engineering problems is often hampered by ambiguities of both terminology and data. This paper attempts to point out some of the problems. After defining "strength" and clarifying related terms, mechanical, physiological, and statistical implications of strength testing are discussed. It becomes obvious that strength data are fully relevant to human engineering problems only if the operator must exert maximal static muscle force; if submaximal forces are required, the applicability of strength data is very limited. Research is needed to establish relations between human static force capacity and the abilities to perform maximal or submaximal dynamic work. At present there is little evidence that static force data accurately predict dynamic performance.

Published in Human Factors, 1970, 12(3), 297-313.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-69-26 March 1970 AD 710 202	Anthropometry of the Air Force Female Hand	Garrett, J.W.

ABSTRACT: This report contains descriptions of 56 anthropometric dimensions measured on the hands of 211 Air Force female personnel (WAF, Nurse Corps and Biomedical Sciences Corps), aged 18-56. Summary statistics including the means, standard deviations, ranges, selected percentiles, measures of

distribution and coefficients of variation are presented for the 56 dimensions. 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.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-69-42 March 1970 AD 709 883	Anthropometry of the Hands of Male Air Force Flight Personnel	Garrett, J.W.

ABSTRACT: This report contains descriptions of and data on 56 anthropometric dimensions of the hands of 148 male Air Force flight personnel. Selected dimensional comparisons indicate that this sample is representative of the total group of Air Force flight personnel. 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 U.S. Air Force 12-size glove program revised to reflect the latest anthropometric data is presented in the appendix.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-69-57 February 1970 AD 707 142	Foot Operation of Controls: Speed of Activation and Exertion of Force to Pedals; Perception, Speed and Accuracy of Leg and Foot Motions	Kroemer, K.H.E.

ABSTRACT: The literature pertaining to foot operation of controls is reviewed and a new experiment reported.

Published experimental results clarify only some isolated aspects of leg and foot motions. Even the relatively often investigated speed of operating pedals and forces that can be applied to them were studied under such different experimental conditions that no general statements are possible concerning what pedal can be operated most quickly or forcibly. Opinions about the advantages and disadvantages of hand versus foot operation seem not generally based on experimental findings.

In an experiment, 20 seated young adult male subjects moved their right foot as rapidly as possible over distances of 15 cm to circular targets. The direction of these discrete movements had no appreciable effect on the accuracy of motion. Forward motions of the vertical or almost vertical lower leg were slightly faster than backward or lateral motions of the elevated lower leg. All motions could be performed in about 0.1 seconds.

Published in Ergonomics, 14:3, 333-361, 1971.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-69-61 February 1970 AD 706 411	The Anthropology of Anthropomorphic Dummies	Hertzberg, H.T.E.

ABSTRACT: This paper describes anthropological aspects of a cooperative program to create a "family" of anthropomorphic dummies representative of the American population. The dummies are for use in crash-tests to improve public safety in motor vehicles. The anthropomorphic dummy is that type which closely approximates a given percentile level of the human body in size, form, segment mobility, total weight, segment weight, weight distribution and resiliency of its "flesh" covering, and is usually able to withstand 100 G. The history of this development is briefly sketched from its beginning in 1949. In the current program, the best available data have been chosen for three adult sizes: the 95th- and 50th-percentile males, and the 5th-percentile female. The body-forms being sculptured will provide a set of national standards for size, shape and weight. Future phases will involve the development of dummy organ-masses approximating the sizes and vibratory responses of those in the living torso. Deficiencies of the anatomical, anthropometric, biomechanical and physiological data used for these bodyforms are noted, and suggestions are made for improvement, so that future dummies may be made more reliably representative of the using population.

This paper originally appeared as No. 690805 (pages 201-214) of the Proceedings of the Thirteenth Stapp Car Crash Conference, published in December 1969, and was presented to the Conference in Boston, Mass., on 2-4 December 1969.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-69-70 August 1969 N70-29085 AD 710 622	Weight, Volume, and Center of Mass of Segments of the Human Body	Clauser, C.E., J.T. McConville, & J.W. Young

ABSTRACT: This study was designed to supplement existing knowledge of the weight, volume, and center of mass of segments of the human body and to permit their more accurate estimation on the living from anthropometric measurements. Weight, volume, and center of mass of 14 segments of the body were determined on 13 male cadavers. Presented are descriptive statistics of these variables as well as a series of regression equations predicting these parameters from anthropometry. Included in the seven supporting appendices are reports of studies of the mid-volume of segments as an approximation of their center of mass, relationships between standing and supine anthropometry and postmortem changes in gross body size, and comparisons between densities of fresh and preserved human tissues.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-69-107 December 1969 AD 705 450	The Relationship of Strength to Body Size and Typology	Laubach, L.L., & J. T. McConville

ABSTRACT: 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. Simple and selected partial correlations were calculated and the results interpreted at the 0.05 level of significance.

The zero-order correlations revealed that body weight, lean-body mass and mesomorphy yielded the highest correlations with mean total strength. Stature, skinfold measurements and the length of the lever arms of the body were not related to mean total strength; however, the relationship between the strength and length of specific torso and arm linkages while weak is definitely indicated. The first-order partial correlations (weight held constant) between body-size measures, lean-body mass and strength measures were about the same as the identical zero-order correlations; however, with weight held constant the skinfold measurements yielded many significant correlations with muscle strength. By holding the effects of stature constant the somatotype components produced several significant correlations with the static-strength measures. The second-order partial correlations (weight and stature held constant) revealed that the sub-scapular and suprailiac skinfolds are more of a factor in the exertion of static strength than the triceps skinfold.

It would appear that the measures of body size, typology and composition used in this analysis were not effective predictors of muscle strength as measured by the static-contraction method.

Reprinted from Medicine and Science in Sports, Vol 1, No. 4, Dec 69.

<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-69-122 April 1971 AD 724 061	The Adult Human Hand: Some Anthropometric and Biomechanical Considerations	Garrett, J.W.

ABSTRACT: Recent studies of the anthropometry and selected biomechanical characteristics of hands are summarized. These include: (1) conventional anthropometry of male and female hands, (2) the anthropometry of the relaxed hand, (3) comparison of certain engineering anthropometric and performance parameters between bare and pressure-gloved hands, and (4) the ability to retain grips on selected handles under high dynamic loads. The utility of these data for human factors engineering is discussed.

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

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-69-123 October 1970 AD 880 934	Visibility Toward the Ground from Selected Tactical Aircraft	Kennedy, K.W., & D. McKechnie

ABSTRACT: A method of evaluating vision toward the ground from the cockpit eye position is presented and demonstrated on selected aircraft. Consideration is given to the level aircraft attitude for the following cockpits: A-1E Pilot, A-1E Copilot, A7A, A-26A Pilot, A-26A Copilot, C-123B Copilot, F-5A, F-5B Front, F-5B Rear, F-105D, F-11A Pilot, O-1A Pilot, O-2 Pilot, OV-10A Pilot, and RF-4C Front; and to selected attitudes of pitch and roll for the RF-4C Front. Vision toward sectors of terrain, defined in terms of ground radii, slant ranges, and position relative to the aircraft, is expressed as a percent of the total within the sector. These percentages are valid for any altitude since ground radii and slant ranges are expressed as multiples of altitude.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-69-127 October/November 1969 AD 697 455	"Zoom Bag Scenario"	Garrett, J.W., & M. Alexander

ABSTRACT: This article presents the background information concerning the joint efforts of the Anthropology Branch and Pressure Suit Depot, Tyndall AFB, Florida, in conducting anthropological research involving pressure-suited flight personnel.

Published in Interceptor, Volume 11, Number 10-11, pages 20-21.

<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-69-141 February 1972 AD 740 259	Human Engineering the Keyboard	Kroemer, K.H.E.

ABSTRACT: The standard typewriter keyboard serves as a model for keyboards of teletype writers, desk calculators, consoles, computer keysets, cash registers, etc. This man-machine interface should be designed to allow high-frequency, error-free operation with the least possible strain on the operator. This paper discusses several feasible, biomechanical improvements of the keyboard. Some experimental findings are described which support the use of the following design concepts: (a) the keys should be arranged in a "hand-configured" grouping to simplify the motion patterns of the fingers; (b) the keyboard sections allotted to each hand should be physically separated to facilitate the positioning of the fingers, and (c) the keyboard sections allotted to each hand should be declined laterally to reduce postural muscular strain of the operator.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
Preprints of IEEE-GMMS ERS International Symposium on Man-Machine Systems, Cambridge, Eng., September 1969	Foot Operation of Controls: Speed and Accuracy of Foot Motions Between Targets	Kroemer, K.H.E.

ABSTRACT: Circular targets, 15 cm between centers, were arranged in rows or columns of three at the reach envelope of the right foot. The subject, sitting on a short chair, moved his right foot as rapidly as possible from one target to an adjacent one. The thigh was kept horizontal while sagittal motions were performed in steps of 15 degrees between knee angles of 90 degrees (vertical) and 150 degrees (forward), or while lateral motions were performed 15 degrees to the left or right at each knee angle.

From the travel times, obtained from 20 male subjects, and from the segments of the goal targets hit first, the following conclusions were drawn:

Forward motions of the vertical or almost vertical lower leg were slightly faster than either backward or lateral motions of the elevated lower leg. Such discrete motions can be learned very quickly and can be performed in about 0.1 seconds. The posture of the lower leg and the direction of motion had no appreciable effect on the accuracy of motion.

<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-70-3 March 1970 AD 706 888	Anthropological Applications in High Altitude Flight Systems	Alexander, M., J.W. Garrett, & J.C. Robinette

ABSTRACT: Anthropologists can provide data describing the human body as comprehensively as necessary, whether as naked flesh or encumbered with protective equipment from head to toe. This article reflects only some of the research programs pursued in the Anthropology Branch on various phases of the dimensional requirements of the pressure suited man in the man-machine system. The spatial requirements for the man in a cockpit or capsule and on ejection and escape mechanisms or wearing clothing as protection against hostile environmental factors, such as heat, cold vacuum, high g, and radiation, present separate problems for the design engineer that can be helped effectively with the applicable anthropological data.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-70-5 April 1972 LC No. 72-600027 AD 743 113	Anthropometry of Air Force Women	Clauser, C.E., P.E. Tucker, J.T. McConville, E. Churchill, L.L. Laubach, & J.A. Reardon

ABSTRACT: This report describes and summarizes the results of an anthropometric survey of U.S. Air Force women carried out during 1968. Included in the report are a description of the methods and techniques used in the survey, descriptions--visual as well as verbal--of the measuring techniques used, and both uni- and bi-variate statistical summaries.

A total of 137 anthropometric dimensions were measured on a sample of 1,905 U.S. Air Force women: 548 officers or officer trainees and 1,357 enlisted women. This anthropometry included five measures of weight and fat thickness, 30 measures of body height and length, 26 measures of body girths, 15 measures of body breadths and depths, and 12 measures of body surface distance. There were, in addition, 30 measures of the head and face, three of the hand, and two of the feet. Thirteen measurements were remeasures of the subject while she was wearing a foundation garment. Background data gathered included age, rank, military occupation, birthplace, blood type, and age at menarche.

Part A describes the survey and the sample, illustrates the measuring techniques, and provides summary statistics including the mean, standard deviation, coefficient of variation, selected percentiles, measures of skewness and kurtosis, and frequency distribution for each measured variable. A study of the body density of a subsample of 95 women is also included.

Part B provides a variety of correlation and regression equation material, including the complete correlation matrix for age, the basic 124 measurements, grip strength, regression equations for all pairs of variables with at least moderately high intercorrelations, selected partial and multiple correlations and a series of step-wise regression equations.

Part C consists of a set of approximately 400 bivariate frequency tables, plus one trivariate table.

Part D contains abbreviated statistical summaries for a set of indices, a group of computer variables, and for the original measurement data separately for the officers and the enlisted women.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-70-11, 1970 AD 739 170	Industrial Seating	Kroemer, K.H.E.

ABSTRACT: Sitting as a working position is less fatiguing than standing, and can, therefore, be maintained longer. It is also a more stable posture and allows better controlled motions. The sitting posture should be upright, but relaxed, without excessive curvatures of the spinal column, and with the thighs about horizontal. The seated person must be free to choose and change his posture; no specific postures should be forced upon him. There are many interactions among work station design, body posture of the worker, and task performance. Based on anthropometric and biomechanical data, design aspects of work seats as well as of foot rests, office equipment, consoles, work benches, machine stands, and the like are discussed. Recommended dimensions for such work stations are presented.

Published as SME Report AD70-138. Dearborn, MI: Society of Manufacturing Engineers, 1970.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-70-25 July/August 1970 AD 727 259	Misconceptions Regarding the Design and Use of Anthropomorphic Dummies	Hertzberg, H.T.E.

ABSTRACT: This paper is a critique of a British article, "Anthropometric Dummies for Crash Research," by Searle and Haslegrave (Bulletin 5, Motor Industry Research Association, 1969), who sharply criticize an American commercial crash-test dummy. That paper, written by engineers, contains a variety of misconceptions regarding human biology and its influence on the design of crash-test dummies as well as on the choice of data for their

construction. Because these views were widely disseminated in England, it was considered necessary to rebut them by tested principles and data for the benefit of human factors science.

Published in Motor Industry Research Association Bulletin #4, 17-21, July/August 1970, Lindley, Warwickshire, England.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
ASD-TR-70-25 December 1970 AD 880 672	Cockpit Compatibility Studies Conducted with Aircrewmembers Wearing High Altitude Flying Outfits in B-57D, B-57F, F-104B, and F-106B Aircraft	Middleton, R.H., M. Alexander, & K.W. Gillespie

ABSTRACT: This report presents anthropometric measurements of the aircrewmembers, dimensions of the aircrewmembers while wearing the High Altitude Flying Outfit (HAFO) in the uninflated and inflated state, and measurements of the clearance between the aircraft cockpit canopy sills and the aircrewmembers seated in the ejection seat when the seat is in the bottom, neutral, and fully raised positions. All aircrewmembers were measured in accordance with WADC TR 56-365, A Height-Weight Sizing System for Flight Clothing. The aircrewmembers were clothed (fitted) according to these measurements.

The dimensions of the aircrewmembers in the HAFO and the dimensions of the aircraft cockpit canopy sills and ejection seat were evaluated with regard to compatibility and crew-member mobility, visibility, and ability to carry out emergency escape procedures and normal aircraft control operations. It was within these areas that tests and evaluations were conducted, with the results noting those conditions which were unsatisfactory or would degrade the operational capabilities of the aircrew member to function under normal and emergency conditions.

The outfits and aircraft referenced in this report were compatible with the outfits uninflated; however, with the outfits inflated, some difficulty was experienced.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-70-33 September 1970 AD 715 975	Placement of Aircraft Controls	Garrett, J.W., M. Alexander, & C.W. Matthews

ABSTRACT: Data are presented to guide the designer in placing aircraft controls to be operated by lightly clothed or pressure-suited aircrewmembers. The capabilities of 17 subjects wearing various combinations of personal equipment to reach 81 locations with a 180° arc forward of Seat Reference Point were determined. Each subject was tested while wearing personal equipment, consisting of an underarm life preserver, parachute harness and, successively, a K2B flight coverall, an uninflated, and an inflated A/P22S-2 Full-Pressure Suit. The subjects sat in a seat configured to approximate Air Force specifications. During the tests they were restrained in the seat by a lap belt and shoulder straps with the inertial reel locked and again with the inertial reel unlocked. Pictorial descriptions of the dimensions, the reach capabilities of each subject, and recommended design values are presented.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-70-34 May 1970 AD 717 793	Hand-Held Device to Measure Finger (thumb) Strength	Kroemer, K.H.E., & E.M. Gienapp

ABSTRACT: A device that measures the force exerted by the thumb, or fingers, is described. This device is hand-held, easily calibrated, and is adjustable to various hand sizes and digit positions. Thumb strength data from 31 male subjects are reported.

Published in Journal of Applied Physiology, 29:4, 526-527, October 1970.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-70-58 September 1970 AD 727 258	"Average" Man is a Fiction: Range of Sizes is Key to Efficient Work Places	Hertzberg, H.T.E.

ABSTRACT: This paper briefly defines the multidisciplinary field variously termed "Ergonomics" (in Europe), and "Human Factors", "Human Engineering" or "Human Factors Engineering" (in the United States), and outlines the part played therein by the sub-field of Engineering Anthropology. This sub-field's basic subdivisions of anthropometry, workplace design, biomechanics, and studies of human discomfort (due to tissue compression) are briefly described, and some principles of use of such data are illustrated by examples from U.S. Air Force experience. Some significant studies on work seats concerning the determination of discomfort and its amelioration are outlined, and the importance of data regarding body size and seating discomfort for furniture design is emphasized, especially for work seats

and desks. In this connection, recent increases in body size in the American population are noted, and the sources of such data are named. A selected list of 35 references is appended.

Published as part of symposium, "Ergonomics: Man's Newest Environmental Science," in CONTRACT, 86-89, September 1970.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-70-75 October 1971 AD 733 551	Foot Forces Exerted at Various Aircraft Brake- Pedal Angles	Hertzberg, H.T.E., & F.E. Burke

ABSTRACT: This study reports the forces (means and standard deviations) exerted by the foot at various angles of extension about its ankle. A sample of 100 rated pilots was used.

The forces were measured in a cockpit mock-up constructed around a specially instrumented F-80 rudder-pedal assembly. The right rudder pedal (hinged on the rudder bar) could be rigidly set to any desired angle between vertical and 75° forward of vertical. Foot forces were measured at 11 positions of the instrumented brake pedal, for both neutral and extended positions of the right leg, and in three cockpit sizes (37-inch, 39-1/4-inch, and 41-inch)--66 measures on each man. In all three conditions, maximal forces were exerted with a 20° zone between about 15° and 35° forward of vertical. Subjective comfort preferences, expressed by 86 pilots, closely paralleled the force findings. It is concluded that aircraft brake-pedal systems should be designed to maximize the effectiveness of the foot in that optimal zone, and that the same zone should be considered for other foot-operated controls, like automobile accelerator pedals.

Published in Human Factors, 1971, 13(5), 445-456.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-70-114 January 1971 AD 720 252	Horizontal Static Forces Exerted by Men Standing in Common Working Positions on Surfaces of Various Traction	Kroemer, K.H.E., & D.E. Robinson

ABSTRACT: Experiments were conducted to measure maximal isometric horizontal push forces. Twenty-eight male subjects pushed forward with both hands, laterally with the preferred shoulder, and with their backs. Reaction force for body stabilization was provided by a vertical wall, a footrest, or by floor-shoe combinations with coefficients of static friction of approximately

1.0, 0.6, and 0.3. Means, standard deviations, and 5th percentiles of the exerted forces are reported. In comparing the experimental data with results previously published, it is concluded that body weight cannot serve as a reliable predictor for push force capability from floors of various tractions. Estimates for static horizontal push as well as pull force capabilities of one or several men are tabulated in relation to traction available to the operator. An appendix contains coefficients of static friction between nineteen floor materials and eight shoe materials.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-70-124 March 1970 AD 724 506	Towards Standardization of Muscle Strength Testing	Kroemer, K.H.E., & J.M. Howard

ABSTRACT: Male subjects (N = 24) exerted maximal horizontal forces either trying to maintain a constant level over five seconds, or increasing steadily to the subjective maximum, or in vigorous jerks of the body. Statistical analysis ( $p < 0.01$ ) indicated that these different techniques of force generation can result in different peak impulses. For the force maintained over five seconds, different scores (peak, and 12 averages during the exertion period) were extracted from the recorded force curves. Many of the resulting scores were significantly different from the others. Thus, a number of distinctly different "strength" scores resulted either from different techniques of force generation used by the subjects, or from different statistical treatments of the same raw data by the experimenter.

To standardize measures of "strength," a definition of strength, a checklist to control experimental techniques, and a regimen to calculate the strength index are proposed.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-71-52 AD 736 108	Seating in Plant and Office	Kroemer, K.H.E.

ABSTRACT: Sitting as a working position is less fatiguing than standing and can, therefore, be maintained longer. It is also a more stable posture and allows better control of motions. Based on anthropometric and biomechanical data, design aspects of work seats as well as of foot rests, office equipment, consoles, work benches, machine stands, and the like are discussed. Recommended dimensions for such work stations are presented.

Published in American Industrial Hygiene Assn. Journal 32:10, 633-652, 1971.

<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-71-88 August 1972 AD 754 924	Link System of the Human Torso	Snyder, R.G., D.B. Chaffin, & R.K. Schutz

ABSTRACT: The objective of this study has been to develop a quantitative description of the mobility of the human torso. This has been accomplished by a systematic multi-disciplinary investigation involving techniques of cadaver dissection, anthropometry, radiography and cinefluoroscopy, photogrammetric, and computer analysis. Seventy-two anthropometric dimensions were obtained on 28 male volunteers, including bone lengths of the extremities and vertebral landmarks. These subjects were statistically matched for both stature and weight to a 1967 USAF anthropometric survey of 2385 adult males. Both radiographs and photographs from different viewing angles were then taken of the subjects while they performed specific reach motions. Statistical regressions were obtained which describe how specific surface markers and bone reference points move in relation to the elbow position for both seated and standing subjects. The major results of the study are, (1) prediction equations and graphs depicting both surface marker and bone reference point locations for a large range of body positions and specific anthropometric variables, (2) prediction equations and graphs describing how the base of the spine reference point (fifth lumbar spinal surface marker) moves in relation to defined seated and standing reference points for given reaches, and (3) a statistical tabulation with illustrations of 72 anthropometric dimensions. It was found that the surface landmarks selected could predict precise locations of the under-lying anatomical landmarks. Both the prediction equations and graphical results allow the construction of alternative linkage systems of the human torso for design purposes.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-71-102 January 1972 AD 735 315	Pedal Operation by the Seated Operator	Kroemer, K.H.E.

ABSTRACT: This paper attempts to serve three purposes: (1) to summarize the open scientific literature on muscular force applicable to pedals, and on the efficiency of foot motions on or between pedals, depending on the body support and the body posture of the seated operator, (2) to discuss the applicability of such studies in automobile (or other equipment) design, especially to the design, selection, and arrangement of foot-operated controls, and (3) to point out that for most conventional vehicles and equipment, modes of seating and of pedal arrangement and operation follow largely common experience and tradition, and only partly scientific findings. For new man-machine systems, new solutions seem possible.

Published in SAE 720004, Detroit, Michigan, Automotive Engineering Congress, January 1972.

<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-71-107 January 1972 AD 735 316	The Human Buttocks in Sitting: Pressures, Patterns, and Palliatives	Hertzberg, H.T.E.

ABSTRACT: After a brief description of relevant buttock structure, the author presents summary data on buttock size, tuberosity locations, and other dimensions needed for improved seat design, as measured from a sample of 35 young males chosen to approximate the range of USAF flying personnel.

Summary load patterns for two angles of seat back (pelvic inclination) are shown, and suggestions to reduce the discomfort of long-continued sitting are made. Curves and data for successful USAF seat surfaces are presented. Citing recent increases in American body size, the author calls for an anthropometric survey on a national sample in which numerous data needed for automotive and other industrial design would be acquired.

Published in SAE 720005, Detroit, Michigan, Automotive Engineering Congress, January 1972.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-71-119 February 1972 AD 740 930	Human Force Exertions in Aircraft Control Locations	Thordsen, M.L., K.H.E. Kroemer, & L.L. Laubach

ABSTRACT: Experiments were conducted to measure the maximum isometric forces which male subjects could exert at six locations of hand operated aircraft controls. Forces were measured in two vertical and four to eight horizontal directions. The subjects (N = 51) sat in a simulated aircraft seat and exerted forces on a cylindrical handle. Selected anthropometric dimensions were obtained on the subjects and compared with those from the 1967 USAF anthropometric survey of flying personnel. Summary statistics including the mean, standard error of the mean, standard deviation, standard error of the standard deviation, coefficient of variation, symmetry, kurtosis, and selected percentiles are presented for each of the 44 force exertion measures. An analysis of the magnitude and direction of the force components, recorded in a plane orthogonal to the requested direction, is presented for each of the 44 primary force measurements. The intercorrelations for the 44 exertions, and the correlations between the force exertions and the anthropometric dimensions are presented. Test-retest differences are presented for 11 of the subjects who completed the 44 force exertion measurements on two separate occasions.

<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-72-16 April 1973 AD 767 206	COMBIMAN: COMputerized Biomechanical MAN-model	Kroemer, K.H.E.

ABSTRACT: COMBIMAN is an engineering tool to represent geometry and physics of the man-cockpit system:

1. Reservoir of anthropometric information : "Body Form Analog"
2. Representation of body mechanics : "Biomechanical Analog"
3. Ergonomic model of man at his work station : "Ergonomic Analog"

This paper summarizes a literature review, a general discussion of computer models representing the geometry of the operator at his work station, the concept of the mathematical formulation, and the development phases of COMBIMAN.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-72-19 July 1972 AD 747 190	Relationships Among Isometric Forces Measured in Aircraft Control Locations	Laubach, L.L., K.H.E. Kroemer, & M.L. Thordsen

ABSTRACT: Fifty-one male subjects participated in a study designed to measure the maximum ("peak") 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 regression analysis of other force data.

Published in Aerospace Medicine 43:7, 738-742, 1972.

<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-72-40 June 1973	Involuntary Head Movements and Helmet Motions during Centrifuge Runs of up to +6G <sub>z</sub>	Kroemer, K.H.E., & K.W. Kennedy

ABSTRACT: Open-loop centrifuge runs reaching +6G<sub>z</sub> were performed with 13 subjects wearing two different types of helmets: the foam padded standard HGU-2A/P, and the Gentex 129-2 with adjustable web suspension. Weights up to 20 ounces were attached at top and sides. The total maximal load was limited to 40 ounces and the largest lateral off-balance to 15 ounces.

During the centrifuge runs, each subject attempted to maintain his gaze at a target directly in front of him. Hence, no voluntary motion of the head should have occurred. Position of the helmet and of the head were recorded photographically at each g-level. From the photographs, data on actual movements of the head and of the helmet were extracted and subjected to a computer-aided analysis.

Involuntary angular head movements, as well as rotational displacements of the helmet on the head, are discussed in this paper in terms of pitch, roll and yaw. Also described are linear changes in the vertical height of the subjects' eyes. Direction and amount of such motions are discussed with respect to the experimental variables: subjects, magnitude of +g<sub>z</sub>, helmet type worn, mass of helmet assembly.

Published in Aerospace Medicine, 44(6):639-644, June 1973.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-72-45 June 1972	International Anthropometric Variability and Its Effects on Aircraft Cockpit Design	Kennedy, K.W.

ABSTRACT: Attention to the anthropometric characteristics of a consumer population plays an important role in the design of many products. To attain a high level of accommodation in highly complex systems such as air and space craft, severe economic and engineering trade-offs are encountered. Levels of accommodation are variable, and in all cases, very expensive. The subject of this paper is the high performance, single seat, military aircraft cockpit, and the problems to be dealt with in accommodating to the anthropometric requirements of the foreign military user. With the airplane, we find that malaccommodation, when it occurs, not only produces a condition in which the product is not convenient to operate, but one in which the user's safety and the basic mission of the aircraft can be compromised.

Published in Proceedings, Symposium on National and Cultural Variables in Human Factors Engineering, Oosterbeck, The Netherlands, June 1972.

<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-72-46 December 1974 AD A011 537	Designing for Muscular Strength of Various Populations	Kroemer, K.H.E.

ABSTRACT: Hand- and foot-operated controls are the input devices through which the operator effects the performance of manned systems. Selection of the type of control and its location within the reach envelope depend, to a large degree, on biomechanical parameters of all user populations, i.e., mainly on their body dimensions and on their strength characteristics, including motion stereotypes and lateral preferences. Muscular strength for control operation can vary significantly with age, sex, cultural origin, health, training, motivation, and other specific traits of the operator population. This paper discusses several of these variables and their biomechanical implications, and describes techniques and a regimen to design new equipment or modify existing equipment to conform to the strength characteristics of the operator populations.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-72-75 May 1974 AD A011 581	Anthropometry and Kinematics in Crew Station Design	Kennedy, K.W.

ABSTRACT: Attention to the anthropometric and kinematic characteristics of the aircrew member is essential to good cockpit design. Today, applied anthropology is performed by a variety of specialists in many industrial plants as well as research installations. The design problems are many in which anthropometric and kinematic variability must be accommodated. Many are crucial to the safety of the pilot and to the success of the mission. However, not everyone believes that Human Factors specialists have a rightful place in the design sequence.

The magnitude of the variability of body size and proportions among the national military populations of the world is startling to the designer. We find among all American military populations a similar but, of course, lesser variability. Yet, it is sufficiently large, and our systems sufficiently complex, so as to produce a difficult design situation. The condition of current anthropometric and kinematic data is reviewed. Insofar as concerns basic conventional anthropometry on our using military populations, there are ample current data. This, however, is a temporary condition. We find ourselves terribly short in functional anthropometric and kinematic data. This latter condition, it appears, was brought on by two developments: (1) the coming regular use of computers in cockpit design, and (2) the advent of very high performance/high g aircraft and their high acceleration cockpits.

Published in Proceedings of Inter-Agency Conference on Management and Technology in the Crew Systems Design Process, September 1972.

<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-72-93 May 1974 AD A011 580	The Effects of Personal Protective Equipment Upon The Arm-Reach Capability of USAF Pilots	Alexander, M., & L.L. Laubach

ABSTRACT: The lack of published arm-reach data on Air Force flight personnel in actual cockpit situations presents manifest difficulties to the cockpit layout specialist. This paper discusses the results of a study to determine the arm-reach capabilities of aircrewmembers wearing heavy winter flight clothing, survival equipment, and restraint harnesses.

The study was conducted at Loring AFB, Maine. The sample consisted of 16 male subjects (currently active Air Defense Command pilots). The subjects were selected to approximate closely the various height-weight categories in the ADC flying population. A specially designed apparatus was constructed to measure arm-reach capability. Each subject was measured under four conditions: (1) shirt-sleeved with the inertial reel unlocked; (2) shirt-sleeved with the inertial reel locked; (3) wearing his full assembly of flying gear (hereafter referred to as maximum assembly) including the underarm life preserver and parachute harness with the inertial reel unlocked; and (4) wearing the maximum assembly with the inertial reel locked.

The results of the study indicated that there are significant differences in arm-reach capability of pilots while in the shirt-sleeved and maximum flying assembly conditions throughout most of the spatial envelope.

Published in Proceedings of Inter-Agency Conference on Management and Technology in the Crew Systems Design, K.D. Cross and J.J. McGrath, editors, Joint-Army-Navy Aircraft Instrumentation Research Program, Los Angeles, pp 225-233, 1973.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-72-127 May 1973 AD 767 201	Excursions of Head, Helmet and Helmet-Attached Reticle Under +g <sub>z</sub> Forces	Kennedy, K.W., & K.H.E. Kroemer

ABSTRACT: Open-loop centrifuge runs reach +6g<sub>z</sub> were performed with 13 subjects wearing two different types of helmets: the foam-padded standard HGU-2A/P, and the Gentex 129-2 with adjustable web suspension. Rigidly attached to the helmet was a lightweight reticle with its crosshair about 1-1/2 inches in front of the left eye. Masses were attached at top and sides of the helmets. The total maximal load was limited to 40 ounces, and the largest lateral off-balance to 15 ounces. During the centrifuge

runs, each subject attempted to maintain his gaze at a target directly in front of him. Hence, no voluntary motion of the head should have occurred. Position of head, helmet, and reticle were recorded photographically at each g-level. From the photographs, data on actual excursions of the head, helmet, and reticle were extracted and subjected to a computer-aided analysis. Involuntary angular head movements, as well as rotational displacements of the helmet on the head, are discussed in this paper in terms of pitch, roll and yaw. Also described are linear changes in the vertical height of the subjects' eyes. Reticle displacements are discussed as they occurred in a frontal y-z plane.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
Published in Human Factors, 1972, 14(1), 3-6	The Law and Our Responsibility	Garrett, J.W.

ABSTRACT: Social and judicial reluctance to accept defectively designed products raises sharp questions concerning the Human Factors engineers' moral, ethical, legal and personal responsibilities. This paper presents one Human Factors engineer's thoughts and opinions on these questions and illustrates situations where liability perhaps should and should not be personal.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
Final Report (Prepared by Webb Associates, Inc., Yellow Springs, Ohio) under U.S. Dept of Health, Education, & Welfare, Contract No. HMS 099-71-11, April 1972. AD 743 113	Anthropometry for Respirator Sizing	McConville, J.T., E. Churchill, & L.L. Laubach Consultant: M. Alexander

ABSTRACT: The research described in this report was undertaken to further the understanding of the proper sizing and design of commercial respirators. Facial anthropometric data from four primary sources (growth surveys, anthropometric surveys of students, health and occupational surveys, and military anthropometric surveys), were examined to determine their appropriateness for use in establishing anthropometric specifications of the head and face of U.S. male and female workers. This report discusses the utility of existing facial anthropometry for respirator design, the preparation of sample respirator sizing programs, and outlines a procedure for evaluation of respiratory fit-test performance.

<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
Chapter 11 (467-584) in Human Engineering Guide to Equipment Design, 2nd ed. (Eds: Van Cott & Kinkade.) U.S. Government Printing Office, Washington, D.C., 1972	Engineering Anthropology	Hertzberg, H.T.E., & K.H.E. Kroemer

ABSTRACT: This chapter presents basic data on human body-size, mobility and strength. Although the bulk of the data stem from U.S. military populations, 60th male and female, because these have been more intensively studied than any others, some anthropometric data are also included for 35 or more non-U.S. populations to emphasize the view that human variation around the world must be considered by designers. Both "structural" (static) and "dynamic" (functional) body-size data are presented, with explanations of how these are used for design purposes. A section on muscle strength and muscle power summarizes extensive experimental data on the maximal and minimal forces exerted by subject samples in numerous test situations.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-73-22 May 1973	Effects of High G on Pilot Muscle Strength Available for Aircraft Control Operation	Kroemer, K.H.E.

ABSTRACT: Experiments were performed to gain information on the isometric strength capabilities on nine G-experienced subjects in centrifuge runs producing +3 and +5g<sub>z</sub>. Their isometric strength was first established in the AMRL/HED biomechanical laboratory. Subsequently, each subject underwent a series of strength tests in the AMRL/DES human centrifuge (open loops mode). At +3 and +5g<sub>z</sub>, the subjects exerted their maximal force forward, backward, to the left and right, up, and down to isometric force transducers located in the positions of stick, throttle, collective, side-arm controller, and of panel and overhead controls. The results indicate a clear pattern: within the experimental conditions investigated, higher G<sub>z</sub>-loads decreased horizontal forces along the x axis (such as "forward" force at the center stick and the panel control, both in front of the subject). The ability to apply force against the direction of the acceleration (i.e., in the -Z direction, "down") generally increased while the ability to exert force in line with the acceleration (i.e., in the +Z direction, "up") decreased.

Published in Proceedings 44th Scientific Annual Meeting of the Aerospace Medical Assoc., Las Vegas, Nevada, May 1973.

<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-73-54 February 1975 AD A011 545	Human Force Capabilities for Operating Aircraft Controls at 1, 3, and 5 G <sub>z</sub>	Kroemer, K.H.E.

ABSTRACT: The maximum isometric forces adult male subjects could exert at eight locations of hand-operated aircraft controls were measured at 1, +3, and +5g<sub>z</sub>. Forces were measured in two vertical and four to eight horizontal directions. Selected anthropometric dimensions were obtained on the subjects and compared with those from the 1967 USAF anthropometric survey of flying personnel. Summary statistics including the mean, standard deviation, coefficient of variation, symmetry, kurtosis, and selected percentiles, are presented for each of the 60 force exertion measures.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-73-73 September 1972	Pilot Armreach and Cockpit Control Locator Machine	Alexander, M., J.W. Garrett, & R.R. Riepenhaff

ABSTRACT: This report describes in detail a test apparatus which is used to determine the capability of pilots to reach, grasp, and manipulate a control knob located at various angles and heights above the floor level. The apparatus consists basically of a simulated aircraft seat conforming to specification, a deck representing the floor of the aircraft cockpit, and an upright rod having a series of vertically-aligned knobs located at preselected angular positions.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
Published in Proceedings of the 44th Scientific Annual Meeting of the Aerospace Medical Assoc., Las Vegas, Nevada, May 1973	A Device to Evaluate the Reachability of Aircraft Hand-Operated Controls	Kennedy, K.W.

ABSTRACT: Data describing the inner and outer boundaries of minimum, 5th, 50th, and 95th percentile grasping reach capability have been obtained on a series of subjects, selected to be characteristic of the USAF flying population. Restraint techniques simulated a lap belt with shoulders

back and shoulder harness inertia reel locked. The 5th percentile reach envelope, throughout which 95 percent of the population can reach, has been rotated artificially to represent the reach envelopes at seat-back angles from 10 to 70 degrees, and a constant seat-pan angle of +6 degrees. The reference point for the reach envelopes has been moved from Seat Reference Point (SRP) to a point 25 inches above SRP and the reach envelopes redescribed in terms of vertical and horizontal angles and linear distances from this new point.

A Cockpit Reach Evaluator has been fabricated. It is portable and designed to be placed in the aircraft seat and to measure the horizontal and vertical angles and distances from 25 inches above SRP to hand-operated controls. With the measurements obtained, it is a simple matter to ascertain immediately if a hand-controller is suitably located to be reached by 95 percent or more of the flying population.

Further studies will expand the usefulness of the Cockpit Reach Evaluator to include lesser levels of torso restraint and different methods of grasping and manipulating hand controls.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-74-17 April 1975 AD A010 453	Arm-Reach Capability of USAF Pilots as Affected by Personal Protective Equipment	Laubach, L.L., & M. Alexander

ABSTRACT: 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.

Published in Aviation, Space, and Environmental Medicine, 46(4):377-386, April 1975.

<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-74-102 February 1976 AD A025 240	Sampling and Data Gathering Strategies for Future USAF Anthropometry	Churchill, E., & J. McConville

ABSTRACT: 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 military requirements and to accommodate changing military populations. Many sampling schemes are described and evaluated for their utility in meeting specific USAF 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.

The authors offer a definition of adequate accuracy based on a detailed statistical analysis and demonstrate that such accuracy can be obtained from random samples of 350 and matched samples of much fewer subjects. They suggest that with the completion of currently on-going anthropometric surveys no further data-gathering of U.S. military personnel on a massive scale need be undertaken.

A multi-faceted plan for the future acquisition of USAF anthropometric data is recommended. The plan incorporates specific steps designed to up-date basic population data, follow and project secular trends and devise surveys tailored to obtain specific task-oriented information.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
DOT HS-801 430 (AMRL-TR-74-137) March 1975 AD A016 485	Investigation of Inertial Properties of the Human Body	Chandler, R.F., C.E. Clauser, J.T. McConville, H.M. McReynolds, & J.W. Young

ABSTRACT: Knowledge of the anthropometric parameters of the human body is essential for understanding of human kinetics and particularly for the design and testing of impact protective systems. Considerable information is available on the size, weight and center of mass of the body and its segments. This report supplements existing information with data regarding 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 14 segments from each cadaver. Standard and three-dimensional anthropometry of the body and segments was also determined.

This report describes the mathematical rationale and the techniques of measurement in detail. Results of the investigation are given as individual data values as well as summary statistics.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-75-18 July 1976	Mass Distribution of the Human Body Using Bio- stereometrics	Herron, R.E., J.R. Cuzzi, & J. Hugg

ABSTRACT: As the new field of biostereometrics has become more widely known, the potential to use it for computing mass distribution from body shape and density data has attracted growing interest. Biostereometrics is the spatial and spatio-temporal analysis of biological form and function based on principles of analytic geometry. When applied to humans, it constitutes a modern approach to anthropometry. A suitable stereometric sensor is used to locate the three dimensional coordinates of points distributed over the body surface. The coordinates serve as input to a digital computer which is programmed to yield permutations of numerical or analog (graphical or physical) outputs as the application requires.

In the present study, stereophotogrammetry was used to obtain stereometric data in the form of Cartesian coordinates of six segmented human cadavers. Density data provided by the contractor (AMRL) were then used in conjunction with the stereometric data to generate mass, volume, center of mass and principal moments of inertia about the principal axes of inertia with the aid of an IBM 360/50 digital computer.

This study was undertaken to further explore the viability of computing mass distribution from biostereometric data and the best available human density values. Only one part of what was a two part study is reported here. Mass distribution of the same six segmented cadavers was determined experimentally in a companion study undertaken by Chandler et al. (1975). Comparative analysis of the results obtained in the two studies is continuing, but a preliminary examination suggests that the biostereometric and pendulum based measurements of mass distribution correlate very well. If further scrutiny bears out the preliminary findings, the basis for using biostereometrics to compute mass distribution in living humans will have been more firmly established. As more complete and more accurate human density data become available, results based on biostereometrics computation can be expected to come even closer to the "true" mass distribution values. With the growing use of digital computers for analytic and simulation purposes rather than simply as a statistical tool, the potential of biostereometrics for generating biomechanical and biomedical parameters warrants further study and implementation where appropriate.

<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-75-32 May 1976	Muscular Strength of Women and Men: A Comparative Study	Laubach, L.L.

ABSTRACT: 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 that have dealt 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.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-75-38 March 1976	Head and Neck Cooling by Air, Water, or Air Plus Water in Hyperthermia	Kissen, A.T., W.C. Summers, W.J. Buehring, M. Alexander, & D.C. Smedley

ABSTRACT: The effects of air, water, and air plus water head cooling on thermoregulatory responses and human operator performance were studied in nonacclimatized, heat-exposed men. Forty chamber exposures (46° C, 30 mm Hg water vapor pressure) were conducted under noncooled and the aforementioned subconditions of head cooling. Five subjects, exposed for 80 min, were monitored for mean skin and rectal temperatures, heart rate, sweat loss, and compensatory tracking performance. A modified Air Force helmet shell provided facial air ventilation (24° C) at eight cfm. Eight interconnected neoprene modules fastened beneath a helmet liner provided water cooling (20° C at 0.9 liters/min). Tracking performance was unchanged across conditions. Elevation of rectal temperature and heart rate, sweat loss, and Physiological Index of Strain were significantly reduced by each condition of head cooling. Air is as effective as water as a cooling agent. Air ventilation acts synergistically with water cooling in reducing physiological strain. Relative merits of each approach to head cooling, in an operational context, are discussed.

Published in Aviation, Space, and Environmental Medicine, Vol 47(3): 265-271, March 1976.

<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-75-51 November 1975	Anthropometric Sizing Program for Oral-Nasal Oxygen Masks Based on 1967 U.S. Air Force Survey Data	McConville, J.T., & M. Alexander

ABSTRACT: A new sizing program for oral-nasal masks, based on total facial length, has been developed through an analysis of the 1967 USAF anthropometric survey head and face data. A four-size series of three-dimensional face forms has been sculpted based on this sizing program as a design aid for sizing such masks. This report includes a discussion of the theoretical and practical aspects of the sizing analyses and procedures, and establishes design limits and procurement tariffs for the four sizes of masks. The MBU-12/P oxygen mask, an oral-nasal, pressure-demand type of mask, has been fabricated in accordance with this sizing system using the face forms as sizing guides. The results obtained during fit-tests using 66 USAF personnel as subjects are described. The authors concluded that the dimensional sizing of the oral-nasal oxygen mask facepieces is valid for USAF flight crews.

Published in Aviation, Space, and Environmental Medicine, November 1975.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-75-111 March 1976 AD A025 773	Paths of Movement for Selected Body Segments During Typical Pilot Tasks	Ayoub, M.M., S. Deivanayagam, & K.W. Kennedy

ABSTRACT: This report describes the geometry of paths of motion for body segments when the hand travels between selected control locations within an aircraft cockpit. The controls selected for this study were the stick, the throttle, the overhead, the panel, the side-arm and the hatch. The control locations (start and end points of the hand travel) were selected to represent both conventional and high acceleration type aircraft cockpits. In addition, three different seat back rest angles (13°, 30° and 65°) were employed to represent the conventional and high acceleration seat configurations. To adequately describe the movements of all body segments, the following landmarks on the body were studied using photogrammetric techniques: Nasion, Cervicale, Suprasternale, Acromion, Shoulder joint center, Elbow joint center, Wrist center, Grip center and Greater Trochanter.

This study was performed as part of the COMBIMAN (COMputerized BIomechanical MAN-model) program of Aerospace Medical Research Laboratory. COMBIMAN when completed will be a computer controlled "manikin" representing a pilot under cockpit environment. This model as a "Biomechanical Analog"

of the pilot, requires as input, certain kinematic data pertaining to the movement of body segments within a cockpit doing typical pilot tasks. This effort was undertaken to provide this movement data for the primary aircraft controls from which kinematic information can be developed.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-75-120 (In Press)	Comparative Muscular Strength of Men and Women: A Review of the Literature	Laubach, L.L.

ABSTRACT: The results from nine separate studies reporting comparable static and dynamic muscle strength measurements between men and women have been reviewed. The statistical data from these studies are presented in graphical and tabular form, each graph illustrating, when appropriate, the mena,  $\pm$  one standard deviation, and the mena percentage difference between men and women for the given measurement.

The following differences in strength measurements were observed: (a) upper extremity strength measurements in women were found to range from 35 to 79% of men's, averaging 55.8%; (b) lower extremity strength measurements in women ranged from 57 to 86% of men's, averaging 71.9%; (c) trunk strength for women ranged from 37 to 70% of men's, averaging 63.8%; (d) dynamic strength indicators revealed that women were from 59 to 84% as strong as men, with an average of 68.6%.

In view of the wide range of mean percentage differences in muscle strength measurements between men and women, the author stresses the importance of exercising extreme care in making extrapolations from such data and recommends a method for making such extrapolations when the absence of direct measurements makes this necessary.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
SLSR #14-75A January 1975 AD A006 342	A Study to Determine the Adequacy of the Tools and Equipment Used by Air Force Women in the Craft Skills	Bolalek, P.J., & A.G. Grumblatt

ABSTRACT: The tools and equipment now used in maintenance, electronics, and civil engineering, were designed to meet the needs of a totally male work force. This study addresses the adequacy of the tools and equipment for the women who are now working in these specialties. The method of approaching this potential problem was to obtain the opinions of the women working in these specialties through self-administered questionnaires.

If more than ten percent of the respondents in a specialty considered a tool or equipment item to be inadequate, that item was considered inadequate for women in that specialty. Twenty-four items were identified as inadequate; size of these items were inadequate in more than one specialty. This study also collected data on the age, height, weight, and hand length of the women working in these specialties. In addition to the identification of inadequate tools and equipment for women, this study found that some of these items may also be inadequate for men. Additionally, potential problems were discovered with the quality of tools used in these specialties and with the suitability of women for these specialties. Further study was recommended in all of these areas.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
SAE Paper No. 750424 February 1975	Mass Distribution Properties of the Male Cadaver	Reynolds, H.M., C.E. Clauser, J.T. McConville, R.F. Chandler, & J.W. Young

ABSTRACT: Mass distribution properties of the human body and its 14 primary segments were measured in three-dimensions using six male cadavers. Data collected include anthropometry, mass, center of mass, and the principal moments of inertia. The principal moments of inertia were computed using a 3 x 3 matrix of values derived from simple pendulum measurements about six non-parallel axes.

Anatomical segmentation procedures used are emphasized and compared with those in previous investigations. In addition, comparisons of the measured data with extant data in the literature on the whole body and its segments are presented and discussed.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AGARD-AG-205 April 1975 AD A010 674	A Review of Anthropometric Data of German Air Force and United States Air Force Flying Personnel 1967-1968	Grunhofer, H.J., & G. Kroh

ABSTRACT: The study contains anthropometric data of GAF and USAF flying personnel. The hitherto unpublished data of German Air Force flying personnel were taken from measurement programs performed in 1967 and 1968 by a team of the German Air Force Institute of Aviation Medicine,

Furstenfeldbruck, Germany, (GAF IAM). They include 153 different body dimensional data of more than 1400 subjects. The data for USAF flying personnel were taken from measurements of 2420 subjects in 1967. These data represent the latest state of anthropometric surveys of American flying personnel.

For each body dimension the following detailed informations are given:

- . The definition, written and illustrated, of body dimension to be measured.
- . The frequency of certain ranges.
- . A breakdown of GAF and USAF data in percentile, permitting comparison.
- . Essentials on the statistics of data distribution.

To facilitate further anthropometric studies the correlation matrix of GAF data has been added in the appendix. The tables contain the correlation coefficients of any anthropometric body dimension with any other listed in this study.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
Presented at the Aerospace Medical Assoc., May 1976, Bal Harbour, Florida	Effects of Encumbering Clothing, Personal-Protective Equipment & Restraints on Body Size & Arm Reach Capability of USAF Aircrewmn	Alexander, M., L.L. Laubach, & J.T. McConville

ABSTRACT: Basic anthropometric dimensions provide engineers and designers with data on the range of body size variability that must be accommodated in the design and development of clothing, personal-protective equipment and workspaces. Designers of cockpits and similar workspaces must also be cognizant of the growth in body size associated with various configurations of clothing and personal-protective equipment and the effects of these assemblies on the arm reach of the users.

A study of a stratified sample of 32 USAF pilots wearing their operational assemblages of over-land and over-water winter flight gear and equipment was conducted. The study determined changes in critical workspace dimensions and arm reach performance due to encumberments of the clothing and equipment. The results of the investigation indicated changes occurred both in body size and performance which are of significance to designers.

<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
Presented at the Aerospace Medical Assoc., May 1976, Bal Harbour, Florida	Estimating Relaxed Tolerance to +G <sub>z</sub> Accelerations Through the Use of Drawing Board Manikins	Kennedy, K.W.

ABSTRACT: The specification of seat-back angle alone is insufficient as a predictor of population tolerance to +G<sub>z</sub> accelerations. It is possible, for instance, to obtain a 4g range in predicted tolerance, depending upon upper back and head rest configuration, with a series of seats each with a 65° back angle. It is also easily possible to derive back angle-head rest combinations that will permit relaxed tolerance to very high +G<sub>z</sub>, but intolerable in terms of pilot acceptability.

To provide greater understanding of the effects on g tolerance brought on by different basic geometries of seated and semi-reclined (high acceleration) positions, it is essential to be able to estimate the positions of the eyes, aortic valves, and carotid sinuses. These relationships can now be quickly and conveniently tracked using the AMRL Drawing Board Manikins. Rather than seat-back angle, the relationship between these anatomical landmarks should be the driving force for laying out the geometry of high-g body support systems.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-76-29 May 1976, AD A025 750	Statistical Concepts in Design	McConville, J.T., & E. Churchill

ABSTRACT: In seeking a manageable way to deal with variations for a large range of body sizes, it is a common practice for designers to construct drafting board manikins, three-dimensional forms or computer simulations as human analogues. Often these analogues are based upon 5th, 50th, or 95th percentile values. Limitations of this approach are discussed in this paper which demonstrate fallacies underlying the assumption that (1) the proportionality of various sized individuals is the same and (2) that percentiles for body dimensions are additive.

Focusing on the 5th and 95th percentile body forms where deviations in size and proportionality are most severe, the report recommends an improved approach to portray the body size of these segments of the population in design problems. A statistical analysis is made of the tails of the height-weight distribution to demonstrate the usefulness of subgroups or regression values. It is suggested that, for many design purposes, subgroup or regression values be used which would maintain statistical integrity in simulations and, at the same time, portray the ends of the distribution more accurately than is presently done.

<u>Report Number and Date</u>	<u>Title</u>	<u>Author</u>
AMRL-TR-76-30 To be presented at the IEA/HFS Congress, July 1976, College Park MD	Computerized Biomechanical MAN-model	McDaniel, J.W.

ABSTRACT: The COMputerized BIomechanical MAN-model (called COMBIMAN) is a computer interactive graphics technique for workplace design. This model allows a designer to manipulate a three-dimensional man form of variable anthropometry and to design a workplace around this man-model by means of a light pen while sitting at a CRT. While originally intended for aircraft design and evaluation, the general format of the model allows it to consider virtually any workplace configuration. Among the functions of COMBIMAN described in this paper are (1) the capability to represent the anthropometry of many populations, (2) the capability to exercise variations of body proportions, (3) interaction with a workplace to determine complex hand and foot reach envelopes, (4) reaching to controls in a realistic path of motion, (5) evaluating workplace task incompatibilities, (6) mapping the fields-of-view of the man-model within a workplace, and (7) determining distances between any points in three-dimensional workplace. Although the COMBIMAN is only displayed or printed in a two-dimensional format, the man-model and workplace exist and interact in three-dimensional space. The model can be used to evaluate existing or theoretical workplace with equal ease and precision.

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<u>Report Number and Date</u>	<u>Title</u>	<u>Authors</u>
AMRL-TR-76-32 To be presented at the IEA/HFS Congress, July 1976, College Park MD	Anthropometric Assessment of Mass Distribution Characteristics of the Living Human Body	McConville, J.T., & C.E. Clauser

ABSTRACT: Techniques have long been sought for estimating accurately the weight, volume, location of the center of mass, and the principal moments of inertia of segments of living human beings. In a recently completed Federal Aviation Administration-United States Air Force study during which these parameters were measured on 14 segments of six male cadavers, stereophotographs of each segment were made. Estimates by the Biostereometrics Laboratory, Texas Institute of Rehabilitation of the same mass distribution characteristics measured on the cadavers were made by analyses of the photographs. Results of the cadaver and stereometric studies are summarized and compared. Techniques are suggested for measuring mass distribution characteristics of living human beings for permitting the collection of such data on samples adequate to describe population parameters.