(2)

TECHNICAL REPORT
NATICK/TR-90/032

AD____________

AD-A224 986

1988 ANTHROPOMETRIC SURVEY OF US ARMY PERSONNEL: CORRELATION COEFFICIENTS AND REGRESSION EQUATIONS

PART 1
STATISTICAL TECHNIQUES, LANDMARK, AND MEASUREMENT DEFINITIONS

BY

JAMES CHEVERUD
CLAIRE C. GORDON*
ROBERT A. WALKER*
CASHELL JACQUISH
LUCI KOHN
ALLEN MOORE
NYUTA YAMASHITA

20030206112

MAY 1990

FINAL REPORT
APRIL 1989 - MARCH 1990

UNITED STATES ARMY NATICK
RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
NATICK, MASSACHUSETTS 01760-5000
NORTHWESTERN UNIVERSITY, EVANSTON, ILLINOIS 60201
*SOLDIER SCIENCE DIRECTORATE

DISCLAIMERS

The findings contained in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Citation of trade names in this report does not constitute an official endorsement or approval of the use of such items.

DESTRUCTION NOTICE

For Classified Documents:

Follow the procedures in DoD 5200.22-M, Industrial Security Manual, Section II-19 or DoD 5200.1-R, Information Security Program Regulation, Chapter IX.

For Unclassified/Limited Distribution Documents:

Destroy by any method that prevents disclosure of contents or reconstruction of the document.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; Distribution unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S) NATICK/TR-90/032
6a. NAME OF PERFORMING ORGANIZATION Northwestern University 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION U.S. Army Natick RD&E Center
6c. ADDRESS (City, State, and ZIP Code) Evanston, Illinois 60201	7b. ADDRESS (City, State, and ZIP Code) Natick, Massachusetts 01760-5000
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable) STRNC-YBF	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER Contract DAAK60-89-C-1006
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. 728012.12 PROJECT NO. OMA TASK NO. WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
1988 ANTHROPOMETRIC SURVEY OF U.S. ARMY PERSONNEL: CORRELATION COEFFICIENTS AND REGRESSION EQUATIONS Part 1 Statistical Techniques, Landmark, and Measurement Definitions

12. PERSONAL AUTHOR(S) James Cheverud, Claire C. Gordon*, Robert A. Walker*, Cashell Jacquish, Luci Kohn, Allen Moore, and Nyuta Yamashita

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 1 Apr 89 TO 31 Mar 90	1990 May	76

16. SUPPLEMENTARY NOTATION
*Affiliated with Soldier Science Directorate, U.S. Army Natick Research, Development, and Engineering Center

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
ANTHROPOMETRY, HUMAN BODY SIZE, MEN, ANTHROPOMETRIC SURVEY, MEASUREMENTS, WOMEN, ANTHROPOMETRIC DATA, DIMENSIONS, ARMY

19. ABSTRACT (Continue on reverse if necessary and identify by block number)
In this five-part series of reports are tabulated the statistical relationships among anthropometric measurements so that designers of Army materiel systems will be able to utilize the data in improving the man-materiel interface. The kinds of statistical relationships tabulated include simple correlations, partial correlations, bivariate regressions and multiple regressions. The simple correlations, partial correlations, and bivariate regressions are among all pairs of characters. Four sets of partial correlations are included, partialling out: stature only; weight only; stature and weight simultaneously; and stature, weight, and age simultaneously. Standard multiple regressions include specific anthropometric dimensions regressed on standard pairs of measurements. Stepwise multiple regressions were also calculated for each anthropometric dimension using the first five independent variables selected in the stepwise procedure. All analyses were performed separately for males and females and are reported separately in the tables. (Continued)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Dr. Robert A. Walker	22b. TELEPHONE (Include Area Code) 508-651-4157 22c. OFFICE SYMBOL STRNC-YBF

DD Form 1473, JUN 86 Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

Box 19--Abstract (Continued)

1988 Anthropometric Survey of US Army Personnel: Regression Equations and Correlation Coefficients appears in five parts, as follows. Part 1 Statistical Techniques, Landmark, and Measurement Definitions (pp. 1--51), NATICK/TR-90/032; Part 2 Simple and Partial Correlation Tables--Male (pp. 52--312), NATICK/TR-90/033; Part 3 Simple and Partial Correlation Tables--Female (pp 313--572), NATICK/TR-90/034; Part 4 Bivariate Regression Tables (pp. 573--853), NATICK/TR-90/035; Part 5 Stepwise and Standard Multiple Regression Tables (pp. 854--984), NATICK/TR-90/036.

The report, 1988 Anthropometric Survey of US Army Personnel: Bivariate Frequency Tables, part of the same contract, is complete in one volume, NATICK/TR-90/031.

References for the series appear at the end of Part 5.

CONTENTS

CONTENTS--(continued)

PREFACE

This report was prepared for use by Army and other personnel in designing human-materiel interfaces. The work was begun in the Department of Cell Biology & Anatomy, Northwestern University, Evanston, IL and completed in the Department of Anatomy & Neurobiology at the Washington University School of Medicine, St. Louis, MO. We wish to thank the contract administrators at both institutions and at the U. S. Army Natick Research, Development, and Engineering Center for their help in facilitating the work, especially in regard to moving the project in midstream.

This report was prepared by James M. Cheverud and colleagues at Northwestern University and Washington University under Army contract DAAK60-89-C-1006 during the period April 1989 through March 1990. Dr. Claire C. Gordon was the project director of the U. S. Army 1988 Anthropometric Survey, and Dr. Robert A. Walker was the project officer for the contract. Dr. Gordon and Dr. Walker are affiliated with the Anthropology Group, Materiel Systems Human Factors Branch, Behavioral Sciences Division, Soldier Science Directorate.

CHAPTER I

INTRODUCTION

The Army has the responsibility to provide clothing, personal protective equipment, and workspaces that accommodate the full range of body size variation present in its user population. This mission can be accomplished only with the aid of an anthropometric data base that accurately reflects the body size and shape distributions of soldiers. Recently (1987-1988), the Army updated its 20-year-old data base by conducting a full-scale anthropometric survey that consisted of over 180 body and head dimensions taken on a sample of more than 9000 soldiers.[1] Previous anthropometric surveys were conducted in 1966 for males[2] and in 1977 for females.[3] The demographic composition of the Army has changed dramatically since these earlier surveys in the proportional representation of various age, sex and racial groups.[4] Thus it was apparent in the mid-80s that the Army's anthropometric data base needed to be generated anew in order to account for demographic changes and secular trends in body size and proportion.

The survey featured a sampling strategy in which demographic minority groups were intentionally "oversampled" in order to accommodate anticipated demographic shifts in the Army population and in order to support basic research goals. This methodology will allow researchers to use the data collected to anticipate future changes in the composition of Army's staff. Survey participants were selected at random within their age/gender/race strata at 11 Army posts in the continental United States.

At the close of the survey, a working data base representing the male and female components was created by stratified random sampling of the total data base, such that the age/race distributions of the working subsets exactly match those of the June 1988 Active Duty Army. The working sample contains 1774 male individuals and 2208 females. Demographic details of the working data base sample, along with basic statistics for the measurements taken, can be found in Gordon et al.[1]

In this report we tabulate the statistical relationships among anthropometric measurements so that designers of Army materiel systems will be able to utilize the data to improve the human-materiel interface. The kinds of statistical relationships tabulated include simple correlations, partial correlations, bivariate regressions, and multiple regressions. The simple correlations, partial correlations, and bivariate regressions are among all pairs of characters. Four sets of partial correlations are included, partialling out: stature only; weight only; stature and weight simultaneously; and stature, weight, and age simultaneously. Standard multiple regressions include specific anthropometric dimensions regressed on standard pairs of measurements. Stepwise multiple regressions were also calculated for each anthropometric dimension using the first five independent variables selected in the stepwise procedure. All analyses were performed separately for males and females and are reported separately in the tables below.

A total of 180 anthropometric measurements (see Chapter IV) are included in the analysis. Forty-eight of these are detailed head measurements derived from three-dimensional coordinates measured with an automated headboard device.[5] The remaining 132 measurements were standard anthropometric dimensions representing the size of parts from all over the body.[6] Definitions of each of the measurements analyzed are provided in Chapter IV.

The next three chapters provide a technical description of the statistical analyses performed and the use of the reported statistics (Chapter II), the definitions and illustrations of the various landmarks used in anthropometric measurement (Chapter III), and the definitions and illustrations of the anthropometric measurements themselves (Chapter IV). Following this preliminary descriptive information the various statistical tables are presented in four chapters, one for each type of analysis. Chapter V contains simple and various partial correlation tables for males and, separately, for females. Chapter VI contains listings of all of the bivariate regressions of sufficient strength of association to allow prediction of anthropometric measurement values from others among the total set of measurements analyzed. For each anthropometric variable, Chapter VII includes the multiple regressions with one, two, three, four, and five independent variables that best predict the dependent variable's value. The final chapter, Chapter VIII, includes the multiple regression models for specific sets of dependent and independent variables.

CHAPTER II

STATISTICAL TECHNIQUES

General Statistical Assumptions

When examining anthropometric data it is assumed that the data are normally or bivariate normally distributed and are a random sample of the population from which they were drawn. That is, we assumed that the individuals included were independently ascertained and are representative of all individuals in the Army. The means by which the working data base was generated assures compliance with the random sample assumption while the large sample utilized here assures that the sampling distribution of the parameters will be distributed in a statistically appropriate fashion. With these assumptions, we are able to reliably ascertain the probability that any statistic estimated from this sample is different from zero.

Simple Correlation Coefficients

A simple correlation coefficient (r), sometimes referred to as a Pearson product-moment correlation, is a measure of the strength of the linear relationship between two variables. Its value ranges from -1.00 to +1.00, with -1.00 representing a perfect negative linear relationship (as X increases, Y decreases), 0.00 representing a total lack of linear relationship, and +1.00 representing a perfect positive linear relationship (as X increases, Y also increases) between the variables. A linear relationship occurs when the change in Y (ΔY) over a given change in values of X (ΔX) is constant over the total range of X values under consideration. Deviations from a linear relationship result in a lowering of the absolute value of correlation coefficients.

A simple correlation coefficient between characters X and Y is defined as follows:

$$r_{xy} = COV(X,Y) / \sqrt{(V_x V_y)}, \qquad (1)$$

where COV(X,Y) is the covariance of the two characters and V represents their variance. A covariance measures the extent to which two variables vary in concert. It is positive when individuals with a larger than average value of X are also typically larger than average for character Y, negative when larger than average values of X are typically associated with smaller than average values of Y, and zero when a given value of X may be associated with any value of Y. It is calculated as:

$$COV(X,Y) = [\sum_{i=1}^{N} (X_i - \overline{X})(Y_i - \overline{Y})]/(N-2), \qquad (2)$$

where $\overline{X}$ and $\overline{Y}$ are the average values of X and Y respectively and N is the number of individuals used to calculate the covariance. Another equivalent equation often used in calculation is:

$$COV(X,Y) = \overline{XY} - \overline{X}\,\overline{Y}, \qquad (3)$$

where $\overline{XY}$ is the mean of the cross-product of the two variables. A variance measures the extent of differences among individuals for the character in question. It is calculated as follows:

$$V_X = \sum_{i=1}^{N} (X_i - \overline{X})^2/(N-1), \qquad (4)$$

or, alternatively,

$$V_X = \overline{(X^2)} - \overline{(X)}^2, \qquad (5)$$

where $\overline{(X^2)}$ is the average of the squared values of X. Inspection of these equations indicates that a variance is the covariance of a trait with itself.

A simple correlation is thus a covariance standardized by the level of variation exhibited by the characters. This standardization allows one to compare the strengths of linear relationship across character sets of grossly different levels of variability. Highly variable measurements, such as weight, will have high covariances with all other characters as compared to lowly variable measurements, such as heel breadth. However, because correlations are standardized for levels of variability, they can be directly compared across characters. Thus, inspection of the correlation tables will allow designers to quickly determine which dimensions are associated in the Army population and therefore which character sets need to impact design criteria in an integrated fashion.

It is also important to determine the probability that a particular estimated correlation statistic is significantly different from zero. In finite samples, it is possible that correlations other than zero may be estimated due to random chance errors even when the true population correlation is zero. Thus, we need to determine which of the many correlation coefficients estimated actually indicate a linear association between the variables. In general, an observed statistic is considered significantly different from zero when the probability of obtaining such an observation in the actual population is 5% or less. This test applies to a single statistical determination.

The standard criterion implies that 1 in every 20 independent statistics may appear significantly different from zero by chance alone. However, with the 180 traits in the 1988 Working Data Base, the full matrix of correlations between all traits contains [(180 * 179)/2], or 16,110 different correlation coefficients. With the acceptance of the 5% probability level, one would expect approximately 800 significant correlations by chance alone, even when there is no correlation in the population as a whole. Thus, with multiple statistical comparisons, it can be difficult to determine which correlations are actually not equal to zero and which only appear so. This problem is known as a multiple comparisons problem and is overcome by using the Bonferroni criterion, or Dunn's test, for determining the significance of individual coefficients. Using the Bonferroni criterion, the experimentwise (or collective) error rate for Type I errors (errors in which the null hypothesis of no correlation is falsely rejected) is limited to no more that 5%, so that there is only a 5% probability of an incorrect rejection of the null hypothesis for even a single coefficient out of the entire collection. This probability limitation is accomplished by dividing the error rate per comparison (typically 0.05) by the total number of comparisons made (k, with k = 16,110 in these analyses). Then the probability which must be met for a single coefficient to be considered significantly different from zero is (0.05/k). The significance levels presented in this report represent the Bonferroni significance levels. Threshold correlations, marking the boundary above which individual correlations are significant, were calculated using the Bonferroni significance level (P = 0.05/16,110) and the standard error of the correlation.[7] The threshold correlations are 0.113 in the male sample and 0.085 in the female sample. The threshold correlations differ in the two sexes due to differences in sample size.

Partial Correlation Coefficients

A partial correlation coefficient measures the linear relationship between two variables after other, specified variables have been held constant. The relationship between the two variables of interest is considered independent from their common relationship to a third or further variables. Thus, the partial correlation $r_{xy.z}$ is the correlation between traits X and Y with trait Z held constant. When only one controlling variable is included, the correlation is referred to as a first order partial correlation. It is calculated from the appropriate simple correlation coefficients as follows:

$$r_{xy.z} = (r_{xy} - r_{xz}r_{yz})/\sqrt{[(1 - r_{xz}^2)(1 - r_{yz}^2)]}. \quad (6)$$

A second order partial correlation controls for two variables while a third order partial correlation controls for three variables. The second order partial correlation between X and Y controlling for both W and Z is calculated as:

$$r_{xy.wz} = (r_{xy.z} - r_{xw.z}\, r_{yw.z})/\sqrt{[(1 - r_{xw.z}^2)(1 - r_{yw.z}^2)]} \quad (7)$$

from the first order partial correlations. A third order partial correlation can be calculated from a set of second order partial correlations in a similar fashion. Significance testing for partial correlations is essentially the same as for simple correlations. With samples as large as those included in the working data base, the critical partial correlation values for statistical significance using the Bonferroni criterion are the same as for the simple correlations, at least to the third decimal place.

Partial correlations are calculated when one wishes to focus on that specific linear relationship between two variables which is independent of other factors. In anthropometric analyses, the variables most often 'partialled out' are size variables. For example, size is controlled in order to determine whether individuals of the same size with longer than average arms also tend to have longer than average legs. This analysis is necessary since the simple relationship between arm and leg length may be due merely to the observation that larger people have both longer arms and longer legs rather than being due to some special relationship between arm and leg length. The partial correlations between all trait pairs have been calculated when adjusting for the effects of stature and weight separately, the combined effects of stature and weight, and the combined effects of stature, weight, and age. Thus, these partial correlations can be used to quantify and interpret body shapes.

Bivariate Linear Regression

Bivariate regression measures the linear relationship between a dependent (Y) and single independent (X) variable by estimating the number of unit differences in trait Y which typically accompany a single unit of increase or decrease in trait X. The model used for the linear relationship is:

$$Y = a + b_{y.x} X, \tag{8}$$

where a is the regression constant or intercept identifying the value of Y when X equals zero and $b_{y.x}$ is the regression coefficient or slope indicating the number of unit differences in Y given a single unit difference in X. The regression coefficient is calculated as:

$$b_{y.x} = cov(X,Y)/V_x, \tag{9}$$

where cov(X,Y) and V_x are as defined above. The regression constant is then calculated as:

$$a = \bar{Y} - b_{y.x} \bar{X}, \tag{10}$$

where $\bar{X}$ and $\bar{Y}$ are the means of the independent and dependent variables, respectively. The values estimated for coefficients a and $b_{y.x}$ in this equation are those that minimize the squared deviations of observed Y values from the estimated regression line. This procedure is known as least squares regression.

The use of this regression model, usually referred to as Model I regression, is based on three assumptions: (1) The independent variable, X, is measured without error; (2) the mean values of the dependent variable (Y) are a function of the values of the independent variable (X) and lie on a straight line described by equation 8; and (3) for any particular value of the independent variable (X_i), the dependent variable's (Y) values are independently and normally distributed with constant variance across various values of the independent variable. Assumption 2 was described above in the discussion of simple correlations while Assumption 3 was discussed in general terms at the beginning of the chapter. The first assumption will not generally hold for anthropometric variables, in that all measurements are taken with some degree of error. Even so, when prediction is the main purpose of regression analyses, as it is here, Model I regression is the most appropriate form to use.[7]

The primary purpose for regression coefficients in the context of this report is to allow the prediction of the dependent variable given a specific value for the independent variable. This is accomplished by using equation 8 and treating a, $b_{y.x}$, and X as known and using them to estimate Y. The estimate of Y obtained in this fashion is the most likely, or average, value of Y for the X_i given in the equation. For example, we may predict the value of acromial height, sitting (ACRHTST, standard measurement 4) from acromial height (ACRHGHT, standard measurement 3) in males (see Measurement Definitions and Illustrations, Chapter 4). The appropriate regression equation is:

$$\text{Estimated ACRHTST (mm)} = 128.038 + 0.326 * \text{ACRHGHT (mm)}. \qquad (11)$$

Even though this point estimate is the most likely value of the dependent variable (ACRHTST) given the value of the independent variable (ACRHGHT), normal variation in the dependent value causes individual cases to deviate from the prediction. The standard error of the estimate measures the extent of variation in the dependent variable at any given value of the independent variable. It is the standard deviation of the residuals which, in turn, are the deviations of the observed values from those predicted by the regression model. Thus, we can use the standard error of the estimate ($s_{y.x}$) to provide a likely range of dependent values given the independent value specified. Given the very large sample sizes used here, the normal correction applied to the standard error of the estimate when the independent variable deviates from its mean can be dispensed with here.[7] Thus a 95% confidence interval for estimated values of the dependent variable can be calculated as:

$$\text{Estimated } Y \pm 1.96\, s_{y.x}. \qquad (12)$$

In our example estimating acromial height, sitting from acromial height, given an acromial height of 1442 mm and standard error of the estimate equal to 21.634 mm, the estimated acromial height, sitting is 598 mm and its 95% confidence interval will be 598 mm ± (1.96*21.634), ranging from 556 mm to 640 mm. This means that 95% of the time individuals with an ACRHGHT of 1442 will have ACRHTST values between 556 mm and 640 mm. The independent variable which best predicts a dependent variable is the one with the smallest standard error of the estimate.

Bivariate regression is very closely related to simple bivariate correlation. The regression coefficient can be calculated as:

$$b_{y.x} = r_{xy}\,(s_y/s_x). \qquad (13)$$

where s_i is the square root of the variance (see equation 4). Statistical significance tests are identical for both regression and correlation coefficients. Since the bivariate regression tables only contain equations for which the correlation is greater than 0.50, all regression equations reported are significant ever at the 0.001 level using the Bonferroni criteria.

Another parameter of interest for regression analysis is the coefficient of determination (R^2). The coefficient of determination measures the proportion of variation in the dependent variable which is associated with the independent variable and thus measures the strength of association represented by the regression. This coefficient is simply the square of the correlation coefficient between the two variables. Thus, it ranges from 0 to +1. The higher the coefficient of determination, the more tightly coupled the two variables considered are. The R^2 values reported in these tables have been adjusted for the number of independent variables used in the analysis. This adjustment does not affect the bivariate coefficients of determination but does have a slight effect on the values reported for multiple regressions. In the regression of acromial height, sitting on acromial height, 46.6% of the variation is shared between the variables. Only regression equations with coefficients of determination above 0.25 are included in the tables.

The standard error of the regression coefficient is also provided in the tables. It allows tests of significance for estimated coefficients by allowing calculation of the 95% confidence interval for the estimate. The 95% confidence interval for the regression coefficient is given by ± 1.96 times the standard error of the regression coefficient. For the regression of ACRHTST on ACRHGHT, the standard error of the regression coefficient is 0.008, and the 95% confidence interval of the regression coefficient is (0.310, 0.342). Since the 95% confidence interval does not encompass 0.00, the slope of the regression is significantly different from zero at the 5% level.

It may also be desirable to predict the Y variable in English units as well as in metric units. In the conversion of a regression equation from metric to English units, the value of the slope remains unchanged unless the independent variable is WEIGHT, while the constant and the standard error of the estimate are multiplied by the factor 0.040. In the regression of acromial height, sitting on acromial height, the constant in English units is 5.041 inches, and the equation expressed in English units is:

$$\text{Estimated ACRHTST (in)} = 5.041 + 0.326 * \text{ACRHGHT (in)}, \quad (14)$$

while the standard error of the estimate converted to English units is 21.634 * 0.040 or 0.852 inches. In cases where the independent variable is WEIGHT, the slope is multiplied by the factor 0.147 to convert it from millimeters per centigram to inches per pound. The constant and the standard error of the estimate are multiplied by the factor 0.040. The prediction of acromial height sitting (ACRHTST) in males from weight is expressed in these equivalent equations:

$$\text{Estimated ACRHTST (mm)} = 491.407 + 0.136 * \text{WEIGHT (cg)} \quad (15)$$

$$\text{Estimated ACRHTST (in)} = 19.347 + 0.020 * \text{WEIGHT (lb)}. \quad (16)$$

If one wishes to transform these equations to English units when WEIGHT is the dependent variable, the constant and standard error should be multiplied by 0.268 and the slope by 6.805.

Multiple Linear Regression

Multiple linear regression is useful in the prediction of a dependent variable from several independent variables simultaneously. The analyses tabulated here represent two classes of regression analysis, multiple regression and stepwise multiple regression. The multiple regression equations represent the prediction of each dependent variable from a specified pair of independent variables; stature and chest circumference, stature and shoulder circumference, waist circumference and crotch height, buttock circumference and crotch height, vertical trunk circumference and crotch height, and stature and weight. In contrast, stepwise multiple regression is performed in a systematic manner, such that it results in the best limited subset of predictor variables that accurately predict the dependent variable. The number of independent variables was limited to five for these analyses.

Multiple regression is a relatively straightforward extension of bivariate regression. Typically, the combination of two or more independent variables in a multiple regression allows a more accurate prediction of a dependent variable than can be obtained from a single independent variable alone, as is done in bivariate regression. The general multiple regression model used is:

$$Y = a + b_1X_1 + b_2X_2 + ... + b_kX_k, \quad (17)$$

where the subscripts identify the first, second, third, up to k^{th} independent variable, a is the regression constant or intercept, and b_i is the partial regression coefficient. The partial regression coefficient is the number of unit changes in the dependent variable (Y) per unit change in the indicated independent variable (X_i) when all other independent variables are held constant. It is the unstandardized version of the partial correlation coefficient (equation 6) and can be calculated as follows when there are two independent variables (X and Z):

$$b_x = r_{yx.z} \sqrt{\{[(1-r_{yz}^2) V_y]/[(1-r_{xz}^2) V_x]\}}. \quad (18)$$

The standardizing term in equation 16 is the ratio of variance in Y not associated with Z to variance in X_i not associated with Z. Thus, it is seen that equation 16 is similar in structure to equation 13 relating simple regression and correlation coefficients. Similar, more complex, equations can be derived for multiple regressions with further independent variables, although calculations are usually performed using matrix algebraic algorithms.[7] The regression constant may be estimated as:

$$a = \overline{Y} - b_1\overline{X_1} - b_2\overline{X_2}, \quad (19)$$

although once again the matrix formulation is preferred. The coefficients estimated by these algorithms describe the line for which the squared deviation of observed Y values from Y values predicted by the line of regression are minimized.

In addition to the assumptions described above for bivariate regression, in multiple regression it is assumed that the correlations among the independent variables are not extreme. If correlations among independent variables are very high (greater than approximately 0.95), a multicollinearity problem will exist. This condition will lead to instability of regression coefficient estimates due to the limited amount of unique variance in specific independent variables available for partial correlation with the dependent variable. However, multicollinearity is unlikely to seriously affect prediction using the equations. Inspection of correlation coefficients among regression coefficient estimates indicates that multicollinearity is not a serious problem in these analyses.

All of the regressions presented are individually statistically significant at the 0.001 level and collectively at the 0.05 level using the Bonferroni criterion. Confidence intervals for individual partial regression coefficients are provided in the tables and can be used to derive 95% confidence limits as described in the section on bivariate regression coefficients. Likewise, multiple coefficients of determination are provided, which indicate the proportion of variance in the dependent variable associated with the set of independent variables.

Prediction of dependent variable values from specific sets of values for independent variables is the main purpose of the coefficients presented in this report. The procedure to be followed is the same as in bivariate regression with the simple addition of independent variables. For example, male abdominal extension depth, sitting (ABEXDPST) can be predicted from buttock circumference (BUTTCIRC) and crotch height (CRCHHGHT) using the following equation:

Estimated ABEXDPST(mm) = -42.063 + 0.363 * BUTTCIRC(mm) -0.091 * CRCHHGHT(mm). (20)

Note that all coefficients are statistically significant although crotch height shows no significant bivariate relationship to abdominal extension depth, sitting. The inclusion of additional independent variables can alter the apparent relationship between the dependent and specific independent variables.

The standard error of the estimate provided in the multiple regression tables can be used, as above, to derive confidence intervals for dependent variable estimates. Due to the large sample sizes, and consequent small standard errors for the regression coefficients, inflation of the estimate's confidence intervals due to deviation of the independent variables from their means is minor within the range of the data. If correction is desired, see Sokal and Rohlf[7] (p. 637).

The stepwise multiple regressions were calculated using standard multiple regression procedures after stepwise selection of the appropriate variables. The stepwise procedure was followed in order to choose a set of five independent variables, which would best predict the dependent variable. While the best prediction for any single dependent variable will be obtained from the full set of other variables (179 in this report), such equations become unwieldy and unreliable when applied to samples other than the one used to estimate the equation. Thus, it is preferable to select some subset of independent variables that will produce nearly as accurate a prediction and be more reliably applied to new samples. No stepwise procedure is perfect and the inclusion or exclusion of specific variables from the selected set of independent variables should not be taken as indicating a special relationship with the dependent variable. Potential independent variables showing high correlation with the dependent variable may be excluded from the final equation due to complex and multiple colinearities with independent variables already included in the favored variable set. Also, although stepwise procedures do not necessarily produce the optimal five variable equation, they will typically produce an equation that approaches the optimal one in predictive power.

We used a stepwise forward selection procedure in which independent variables are added to the multiple regression equation sequentially. The first variable entered is the one with the highest coefficient of determination with the dependent variable. The second variable added is the one that causes the greatest increase in the multiple coefficient of determination. This is the variable with the highest partial correlation with the dependent variable, controlling for the first variable entered. Additional independent variables are added, one at a time, using the same criterion. At each step the included variables are reevaluated so that any variable that initially fits the criterion but, with the new complement of independent variables, no longer appreciably increases the coefficient of determination, is removed from the selected set. This procedure was followed until five independent variables were selected. These five variables were then used in a series of five regressions with the independent variable, each further regression including an additional selected independent variable. These regressions are then treated as any other multiple regression, as described above.

CHAPTER III

LANDMARK DEFINITIONS AND ILLUSTRATIONS

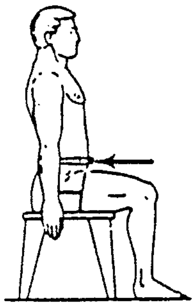
The dimensions are measured from one point on the body (or a fixed surface such as the floor) to another or, in the case of circumferences, around the body at a specified level. To ensure that each dimension is measured accurately and consistently from one subject to the next, dimensions are defined in terms of body landmarks, which serve as the origin, termination, or level of measurement of a dimension.

Two men and two women were trained in locating many of these points by palpation or by sight, and placing actual drawn marks on the bodies of all subjects in this survey. Measurers were also trained to recognize other easily located landmarks such as dactylion II landmark, the tip of the index finger, for which marking was not necessary.

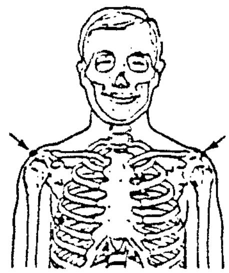
The landmarks used to define the measurements in the survey are briefly described and illustrated over the following pages. Detailed instructions for locating these landmarks can be found in the Measurer's Handbook.[6]

LANDMARKS

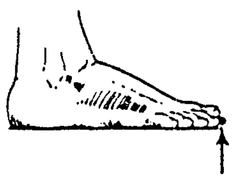
Abdominal point, anterior: The most protruding point of the relaxed abdomen of a seated subject.



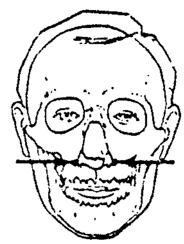
Acromion, right and left: The point of intersection of the lateral border of the acromial process and a line running down the middle of the shoulder from the neck to the tip of the shoulder.



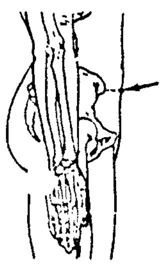
Acropodion: The tip of the first or second toe of the right foot, whichever is longer.



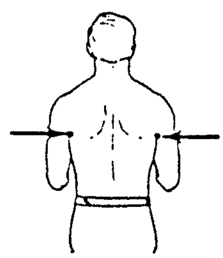
Alare, right and left: The lateral point on the flare or wing of the nose.



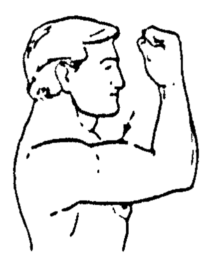
Anterior superior iliac spine, right and left: The anterior points of the right and left iliac crests.



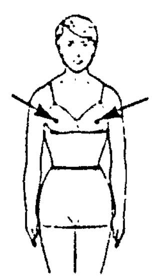
Axillary fold, posterior: right and left: The highest points of the right and left axillary folds on the back.



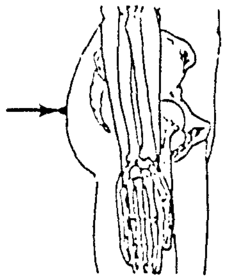
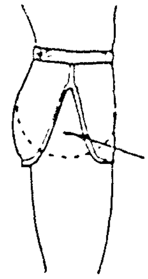
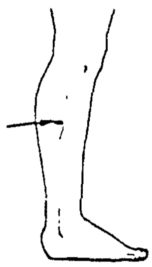
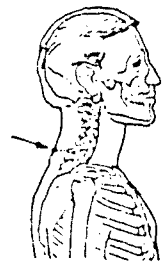
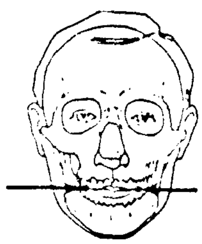
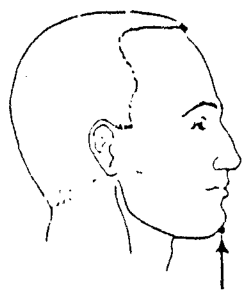
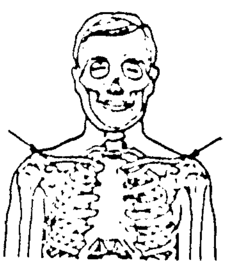
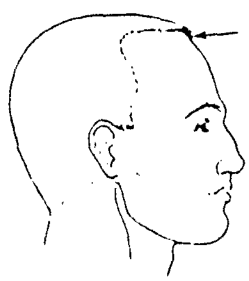
Biceps point: The highest point of the right flexed biceps as viewed from the subject's right side.



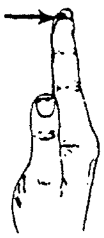
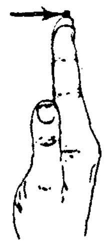
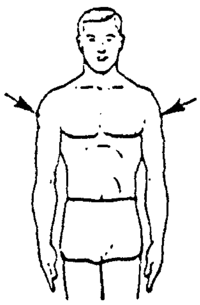
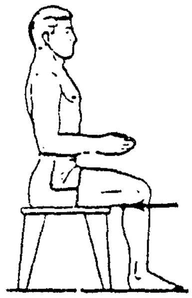
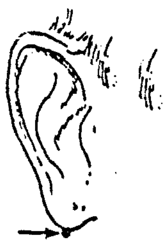
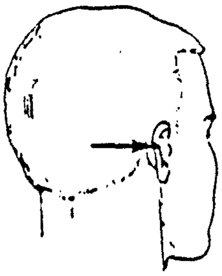
Bustpoint, right and left: The anterior points of the bra cups.

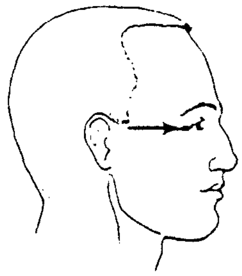
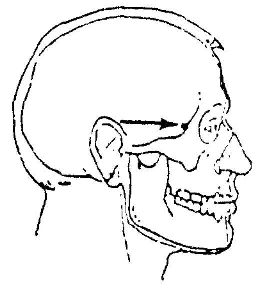
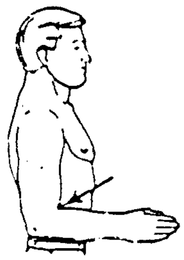
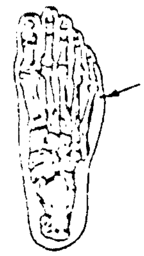
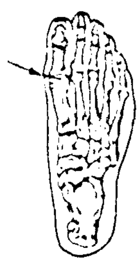
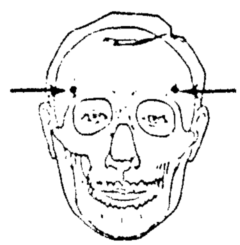
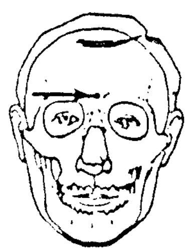
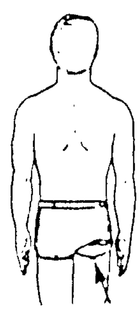


LANDMARKS (cont'd)

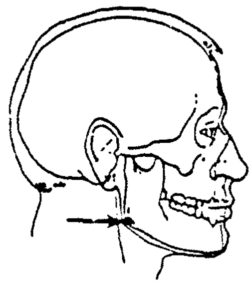
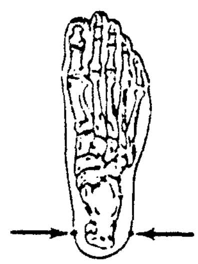
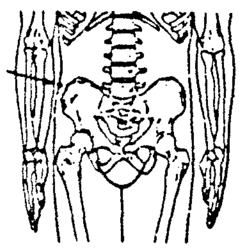
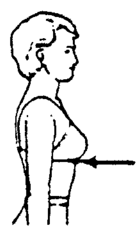
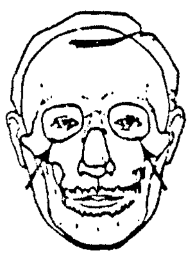
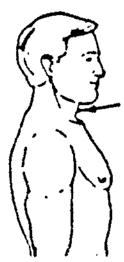
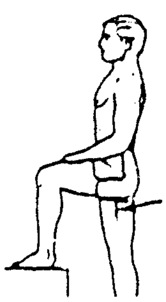
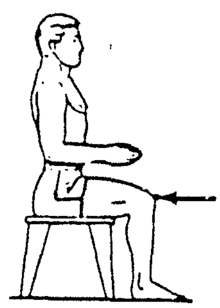
Buttock point, posterior: Point of maximum protrusion of the right buttock of a standing subject. 	**Buttock point, right lateral and left lateral:** Points on the thigh or hip at the level of the maximum protrusion of the right buttock. 
Calf: A point on the side of the calf at the level of the maximum circumference of the right calf. 	**Cervicale:** The superior palpable point of the spine of the seventh cervical vertebra. 
Cheilion, right and left: The lateral point of the juncture of the fleshy tissue of the lips with the facial skin at the corner of the mouth. 	**Chin:** The most protruding point on the bottom edge of the chin, along the jawline. 
Clavicle point, right and left: The superior point of the lateral ends of the clavicle. 	**Crinion:** The lowest point of the hairline on the forehead in the midsagittal plane. 

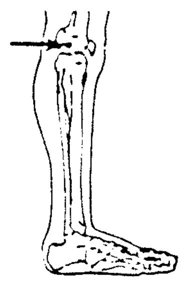
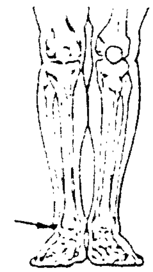
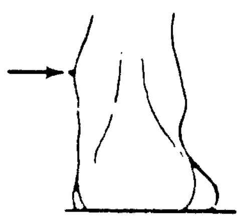
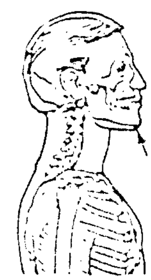
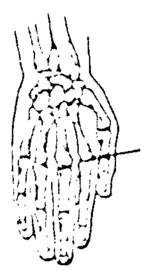
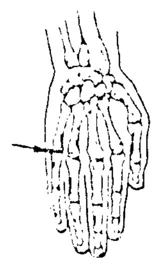
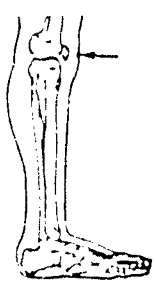
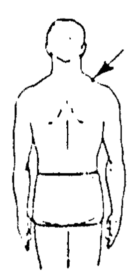
LANDMARKS (cont'd)

Dactylion II: The tip of the right index finger. 	**Dactylion III, right and left:** The tip of the middle finger. 
Deltoid point, right and left: The lateral point of the right deltoid muscle, and the margin of the left deltoid muscle at the level of the right deltoid point. 	**Dorsal juncture of the calf and thigh:** The juncture between the right calf and thigh behind the knee of a subject sitting with the knee flexed 90 degrees. 
Dorsal juncture of the foot and leg: The top of a skin crease between the right foot and the front of the ankle when the knees and ankles are flexed about 30 degrees. 	**Ear, bottom:** The lowest point of the right ear on its long axis. 
Ear point: The lateral point (farthest from the head) of the right ear. 	**Ear, top:** The highest point of the right ear on its long axis. 

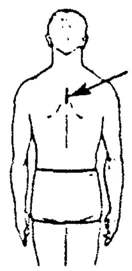
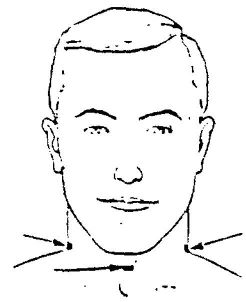
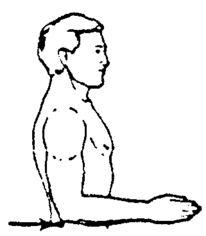
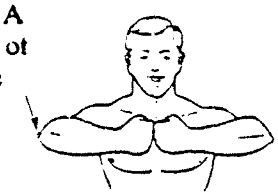
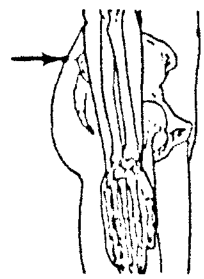
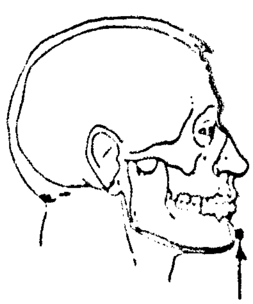
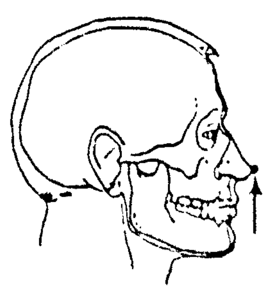
LANDMARKS (cont'd)	
Ectocanthus: The outside corner of the right eye formed by the meeting of the upper and lower eyelids. 	**Ectoorbitale, right and left:** The posterior point on the frontal process of the zygomatic bone at the level of the outer corner of the eye. 
Elbow crease: The skin crease on the inside of the right elbow joint when the elbow is flexed 90 degrees. 	**Fifth metatarsophalangeal protrusion:** The lateral protrusion of the right foot in the region of the fifth metatarsophalangeal joint. 
First metatarsophalangeal protrusion: The medial protrusion of the right foot in the region of the first metatarsophalangeal joint. 	**Frontotemporale, right and left:** The point of deepest indentation of the temporal crest of the frontal bone above the browridges. 
Glabella: The anterior point on the frontal bone midway between the bony browridges. 	**Gluteal furrow point:** The lowest point of the lowest furrow or crease at the juncture of the right buttock and the thigh. 

LANDMARKS (cont'd)

Gonion, right and left: The lateral point on the posterior angle of the mandible (jawbone). 	**Heel point, lateral and medial:** The lateral and medial points of the right heel located at or behind the most protruding point of the lateral malleolus (outside ankle bone). 
Iliocristale: The highest palpable point of the right iliac crest of the pelvis, one half the distance between the anterior superior iliac and posterior superior iliac spines. 	**Inferior breast point:** The inferior point of the juncture of the lower of the two breasts with the torso. 
Infraorbitale, right and left: The lowest point on the anterior border of the bony eye socket. 	**Infrathyroid:** The inferior point in the midsagittal plane of the thyroid cartilage (Adam's apple). 
Inner thigh: A vertical line halfway between the front and back of the right inner thigh, and extending downward from the level of the gluteal furrow. 	**Knee point, anterior:** The most protruding point of the right kneecap of a seated subject. 

LANDMARKS (cont'd)	
Lateral femoral epicondyle, standing and sitting: Lateral point of the right femoral epicondyle (knee pivot point). 	**Lateral malleolus:** The lateral point of the right lateral malleolus (outside ankle bone). 
Medial malleolus: The medial point of the right medial malleolus (inside ankle bone). 	**Menton:** The inferior point of the mandible in the midsagittal plane (bottom of the chin). 
Metacarpale II: The lateral point of the right metacarpo-phalangeal joint II (at the base of the index finger on the outer edge of the hand). 	**Metacarpale V:** The medial point of the right metacarpo-phalangeal joint V (at the base of the little finger on the outer edge of the hand). 
Midpatella: The anterior point halfway between the top and bottom of the right patella (the kneecap). 	**Midshoulder:** The point on top of the right shoulder midway between the neck (right trapezius point) and the tip of the shoulder (acromion, right). 

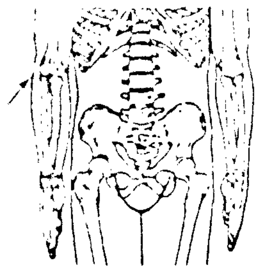
LANDMARKS (cont'd)

Midspine: A line down the center of the back. 	**Neck: anterior, right lateral, and left lateral:** Anterior and lateral points at the base of the neck. 
Olecranon, bottom and rear: The lowest and rearmost points of the right elbow with the elbow flexed 90 degrees. 	**Olecranon, center:** A point on the center of the curvature of the right olecranon process with the elbow flexed about 115 degrees. 
Otobasion superior: The anterior superior point of the juncture between the right ear and the head. 	**Posterior superior iliac spine:** The posterior point of the crest of the right ilium. A dimple normally overlies this point. 
Promenton: The anterior projection of the soft tissue of the chin. 	**Pronasale:** The point of the anterior projection of the tip of the nose. 

LANDMARKS (cont'd)

Pternion: The posterior point of the right heel.

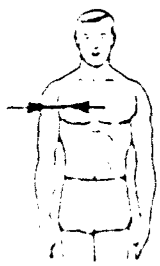
Radiale: The highest point on the outside edge of the right radius.



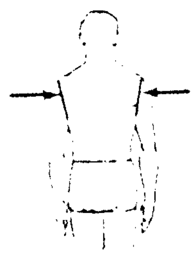
Scye: Points on the upper arm and torso associated with the armhole of a garment.

Anterior scye on the torso: A short horizontal line on the torso originating at the apex of the right anterior axillary fold

Anterior scye on the upper arm: A short horizontal line on the upper arm originating at the apex of the right anterior axillary fold.



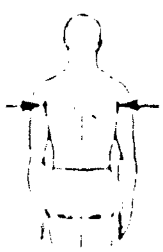
Posterior diagonal scye, right and left: A diagonal line connecting the apex of the posterior axillary fold with the **acromion** landmark on the tip of the shoulder.



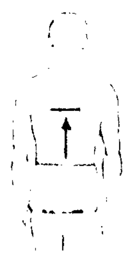
Posterior horizontal scye, right and left: A short horizontal line on the back originating at the apex of the posterior axillary fold.

Midscye, right and left: A short horizontal line bisecting the **Posterior diagonal scye** landmark.

Posterior vertical scye, right and left: A short vertical line on the back originating at the apex of the posterior axillary fold.

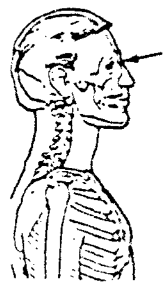


Scye level at midspine: A short horizontal line across the spine at the level of the **Posterior horizontal scye** landmarks.

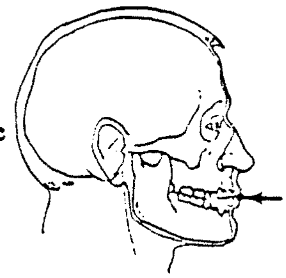


LANDMARKS (cont'd)

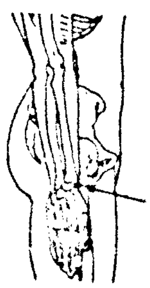
Sellion: The point of the deepest depression of the nasal bones at the top of the nose.



Stomion: The point of intersection of the upper and lower lip in the midsagittal plane when the mouth is closed.

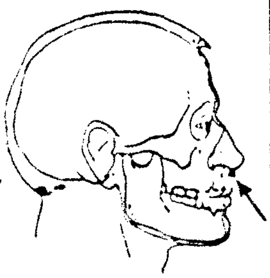


Stylion: The lowest point of the bottom of the right radius.

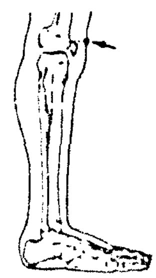


Submandibular: The juncture, in the midsagittal plane, of the lower jaw (mandible) and the neck.

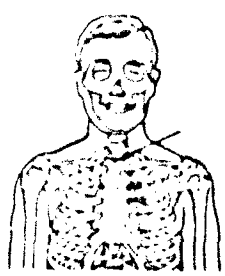
Subnasale: The point of intersection of the philtrum (groove of the upper lip) with the inferior surface of the nose, in the midsagittal plane.



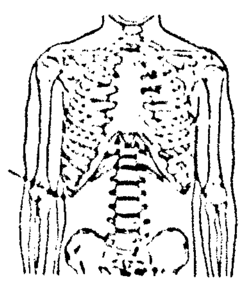
Suprapatella: The superior point of the right patella (kneecap).



Suprasternale: The inferior point of the jugular notch of the sternum (top of the breastbone).

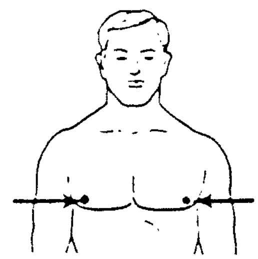


Tenth rib: The inferior point of the right tenth rib (bottom of the rib cage).

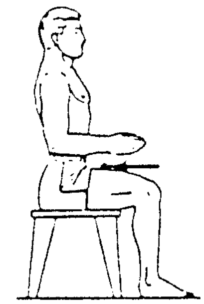


LANDMARKS (cont'd)

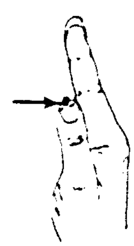
Thelion, right and left: Center of the nipple (on males).



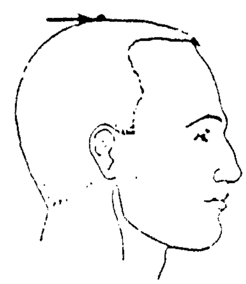
Thigh point, top: The highest point of the top of the right thigh of a seated subject.



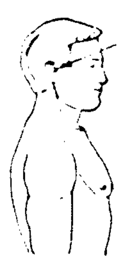
Thumbtip: The tip of the right thumb.



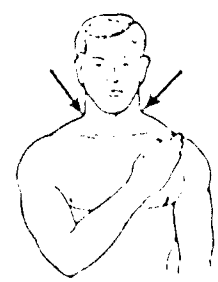
Top of head: The highest point on the head when the head is in the Frankfort plane.



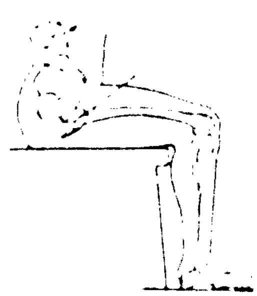
Tragion, right and left: The superior point on the juncture of the cartilaginous flap (tragus) of the ear with the head.



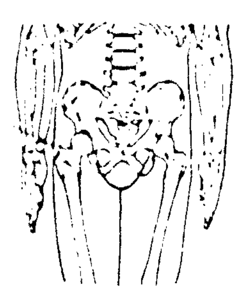
Trapezius point, right and left: The point at which the anterior border of the trapezius muscle crosses the lateral neck landmark.

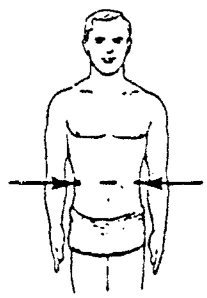
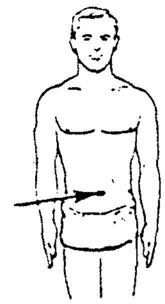
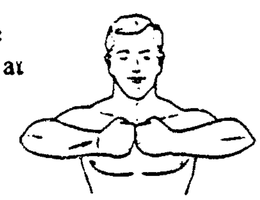
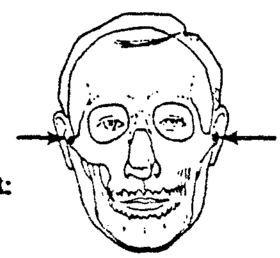
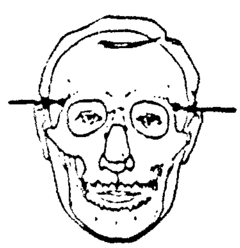


Trochanter: A point at the center of the lateral surface of the greater trochanter of the right femur of a sitting subject.



Trochanterion: The superior point of the greater trochanter of the right femur of a standing subject.



LANDMARKS (cont'd)	
Waist (natural indentation): right and left; **anterior and posterior:** Level of the greatest indentation on the right side of the torso, or half the distance between **10th rib** and **Iliocristale** if no single indentation is clear. 	**Waist (omphalion): right and left; anterior and posterior:** Level of the center of the navel. 
Wrist, dorsal: A line across the back of the right wrist originating at the **stylion** landmark and perpendicular to the long axis of the arm. 	**Zygion, right and left:** The lateral point on the zygomatic arch. 
Zygofrontale, right and left: The lateral point of the frontal bone on its zygomatic process. 	

CHAPTER IV

MEASUREMENT DEFINITIONS AND ILLUSTRATIONS

One hundred thirty-two directly measured anthropometric dimensions were obtained in the survey using standard instruments and methods. Where there was a choice of right or left sides, all measurements were taken on the right side of the body unless specified otherwise or, in rare cases, where an injury or anatomical abnormality made it necessary to measure on the left side. All anthropometric dimensions were recorded to the nearest millimeter and all results reported here for these dimensions are in millimeters. This unit allows standard errors and regression coefficients to be specified with a greater degree of precision than allowed on a centimeter scale. Weight is reported to the nearest 0.1 kilogram. Detailed illustrated instructions for taking the measurements are included in Clauser et al.[7] while detailed definitions are provided in Gordon et al.[1]

In addition to general anthropometric measurements, a series of 48 special head and face dimensions were derived from the three dimensional coordinates of 26 landmarks collected by means of a special automated headboard device.[5] These additional measurements were collected because traditional anthropometric measures do not provide enough detail in the head and face to maximally aid in the design of personal protective equipment, such as helmets, goggles, and respirators.

The sample size analyzed here includes 1774 males and 2208 females. With only minor exceptions, all measurements are available for each individual. The landmark crinion cannot be located on bald subjects or those with receding hairlines. It is also not recorded for individuals with hair transplants. This resulted in the loss of two female and twenty-seven males for crinion - back of the head and crinion - top of the head. Interpupillary breadths were also unavailable for three males and one female whose morphology lay outside the range that could be measured by the device employed for this purpose. These small numbers of missing values have no practical effect on the statistics reported below.

For each standard measurement, the listing provides the variable number used to identify variables in several of the tables below, the full measurement name, an eight character abbreviated name also defined in the data base, and a brief definition. The data base variable numbers are not consecutive because a series of anthropometric measurements derived from the original 132 standard anthropometric measurements are not included in this report. Also in the Tables of this report variable number 1 corresponds to subject ID number.

A visual index of measurement illustrations is provided at the end of the chapter.

Standard Measurement Definitions

Note: All measurements refer to a subject's right side unless otherwise specified.

2 ABDOMINAL EXTENSION DEPTH, SITTING (ABEXDPST) -- horizontal distance between the anterior point of the abdomen and the back at the same level.

3 ACROMIAL HEIGHT (ACRHGHT) -- vertical distance between the standing surface and the acromion landmark on the tip of the shoulder.

4 ACROMIAL HEIGHT, SITTING (ACRHTST) -- vertical distance between the sitting surface and the acromion landmark on the tip of the shoulder.

5 ACROMION-RADIALE LENGTH (ACRDLGTH) -- distance between the acromion landmark at the tip of the shoulder and the radiale landmark on the elbow.

6 ANKLE CIRCUMFERENCE (ANKLCIRC) -- minimum horizontal circumference of the ankle.

7 AXILLA HEIGHT (AXHGHT) -- vertical distance between the standing surface and the axillary fold at the anterior scye landmark on the torso.

8 AXILLARY ARM CIRCUMFERENCE (AXARCIRC) -- circumference of the upper arm perpendicular to its long axis at the level of the anterior scye landmark on the upper arm.

9 BALL OF FOOT CIRCUMFERENCE (BLFTCIRC) -- circumference of the foot at the first and fifth metatarsophalangeal protrusion landmarks on the ball of the foot.

10 BALL OF FOOT LENGTH (BLFTLGTH) -- distance between the back of the heel and the landmark at the first metatarsophalangeal protrusion on the ball of the foot.

11 BIACROMIAL BREADTH (BCRMBDTH) -- posterior distance between the right and left acromion landmarks on the tips of the shoulders.

12 BICEPS CIRCUMFERENCE, FLEXED (BICIRCFL) -- circumference of the upper arm at the level of the flexed biceps point measured perpendicular to the long axis of the arm.

13 BIDELTOID BREADTH (BIDLBDTH) -- maximum horizontal distance between the lateral margins of the upper arms on the deltoid muscles.

14 BIMALLEOLAR BREADTH (BIMBDTH) -- horizontal distance between the maximum protrusions of the ankle bones (medial and lateral malleoli).

15 BISPINOUS BREADTH (BISBDTH) -- distance between the right and left anterior superior iliac spine landmarks.

16 BITRAGION CHIN ARC (BITCHARC) -- surface distance between the right and left tragion landmarks on the cartilaginous flaps in front of the earholes across the chin landmark.

17 BITRAGION CORONAL ARC (BITCOARC) -- surface distance between the right and left tragion landmarks on the cartilaginous flaps in front of the earholes across the top of the head in a coronal plane.

18 BITRAGION CRINION ARC (BITCRARC) -- surface distance between the right and left tragion landmarks on the cartilaginous flaps in front of the earholes across the top of the forehead at the crinion landmark.

19 BITRAGION FRONTAL ARC (BITFRARC) -- surface distance between the right and left tragion landmarks on the cartilaginous flaps in front of the earholes across the forehead just above the ridges of the eyebrows.

20 BITRAGION SUBMANDIBULAR ARC (BITSMARC) -- surface distance between the right and left tragion landmarks on the cartilaginous flaps in front of the earholes across the submandibular landmark at the juncture of the jaw and the neck.

21 BITRAGION SUBNASALE ARCBITSNARC) -- surface distance between the right and left tragion landmarks on the cartilaginous flaps in front of the earholes across the subnasal landmark.

22 BIZYGOMATIC BREADTH (BIZBDTH) -- maximum horizontal breadth of the face between the zygomatic arches.

23 BUSTPOINT/THELION-BUSTPOINT/THELION BREADTH (BSTPTBR) -- distance between the right and left bustpoints on women and the center of the nipples (thelion) on men.

24 BUTTOCK CIRCUMFERENCE (BUTTCIRC) -- horizontal circumference of the trunk at the level of the maximum protrusion of the right buttock.

25 BUTTOCK DEPTH (BUTTDPTH) -- horizontal depth of the torso at the level of the maximum protrusion of the right buttock.

26 BUTTOCK HEIGHT (BUTTHGHT) -- vertical distance between the standing surface and the level of the maximum protrusion of the right buttock.

27 BUTTOCK-KNEE LENGTH (BUTTKLTH) -- horizontal distance between the most posterior point on either buttock and the front of the knee as measured in the sitting position with the knees flexed 90 degrees.

28 BUTTOCK-POPLITEAL LENGTH (BUTTPLTH) -- horizontal distance between the most posterior point on the buttock and the back of the knee as measured in the sitting position with the knees flexed 90 degrees.

29 CALF CIRCUMFERENCE (CALFCIRC) -- maximum horizontal circumference of the calf.

30 CALF HEIGHT (CALFHGHT) -- vertical distance between the standing surface and the level of the maximum circumference of the calf.

31 CERVICALE HEIGHT (CERVHGHT) -- vertical distance between the standing surface and the cervicale landmark at the back of the neck at the maximum point of quiet respiration.

32 CERVICALE HEIGHT SITTING (CERVSIT) -- vertical distance between the sitting surface and the cervicale landmark on the back of the neck.

33 CHEST BREADTH (CHSTBDTH) -- maximum horizontal breadth of chest at the level of the bustpoint/thelion.

34 CHEST CIRCUMFERENCE (CHSTCIRC) -- maximum horizontal circumference of the chest at the level of the bustpoint on women and the nipple on men.

35 CHEST CIRCUMFERENCE AT SCYE (CHSTCISC) -- horizontal circumference of the chest at the level of the scye-at-midspine-landmark.

36 CHEST CIRCUMFERENCE BELOW BREAST (CHSTCB) -- horizontal circumference of the chest at the level of the inferior juncture of the lowest breast with the rib cage.

37 CHEST DEPTH (CHSTDPTH) -- horizontal distance between the chest at the level of the bustpoint on women and the nipple on men, and the back at the same level.

38 CHEST HEIGHT (CHSTHGHT) -- vertical distance between the standing surface and the bustpoint on women and the nipple on men.

39 CROTCH HEIGHT (CRCHHGHT) -- vertical distance between the standing surface and the crotch.

40 CROTCH LENGTH, NATURAL INDENTATION (CRCHLNI) -- distance through the crotch between the abdomen and back at the level of the natural indentation of the waist.

41 CROTCH LENGTH, OMPHALION (CRHLOM) -- distance through the crotch between the navel and the same level on the back at the waist.

42 CROTCH LENGTH, POSTERIOR NATURAL INDENTATION (CRLPNI) -- surface distance from the crotch at the inner thigh landmark to the back of the waist at the natural indentation of the waist.

43 CROTCH LENGTH, POSTERIOR OMPHALION (CRLPOM) -- surface distance from the crotch at the inner thigh landmark to the back of the waist at the omphalion.

44 EAR BREADTH (EARBDTH) -- maximum breadth of the ear perpendicular to its long axis.

45 EAR LENGTH (EARLGTH) -- length of the ear from its highest to lowest points on a line parallel to the long axis of the ear.

46 EAR LENGTH ABOVE TRAGION (EARLTRAG) -- distance from the tragion landmark to the top of the ear on a line parallel to the long axis of the ear.

47 EAR PROTRUSION (EARPROT) -- horizontal distance between the mastoid process and the outside edge of the right ear at its most lateral point.

48 ELBOW CIRCUMFERENCE (ELBCIRC) -- circumference of the elbow in a plane perpendicular to the long axis of the arm at the level of the olecranon center landmark, with the arm straight at the side.

49 ELBOW REST HEIGHT (ELRHGHT) -- vertical distance between the sitting surface and the olecranon landmark on the bottom of the flexed elbow.

50 EYE HEIGHT, SITTING (EYEHTSIT) -- vertical distance between the sitting surface and the ectocanthus landmark at the outer corner of the eye.

51 FOOT BREADTH, HORIZONTAL (FTBRHOR) -- maximum breadth of the standing foot between the first and fifth metatarsophalangeal landmark protrusions.

52 FOOT LENGTH (FOOTLGTH) -- distance between the tip of the longest toe and the back of the heel of the standing foot.

53 FOREARM CIRCUMFERENCE, FLEXED (FCIRCFL) -- maximum circumference of the forearm just above the elbow crease with the elbow flexed 90 degrees and the fist tightly clenched.

54 FOREARM-FOREARM BREADTH (FORFORBR) -- maximum horizontal distance between the lateral right forearm and the lateral left forearm.

55 FOREARM-HAND LENGTH (FORHDLG) -- horizontal distance between the back of the tip of the elbow to the tip of the middle finger.

56 FUNCTIONAL LEG LENGTH (FNCLEGLG) -- straight-line distance when seated with the leg extended between the footrest surface of the anthropometer and the posterior surface of the body.

57 GLUTEAL FURROW HEIGHT (GLUFURHT) -- vertical distance between the standing surface and the lowest point of the gluteal furrow under the buttocks.

58 HAND BREADTH (HANDBRTH) -- maximum breadth of the hand between the metacarpal II and metacarpal V.

59 HAND CIRCUMFERENCE (HANDCIRC) -- maximum circumference of the hand at the level of the metacarpal II and metacarpal V.

60 HAND LENGTH (HANDLGTH) -- length of the hand between the stylion landmark on the wrist and the tip of the middle finger.

61 HEAD BREADTH (HEADBRTH) -- maximum horizontal breadth of the head above the attachment of the ears.

62 HEAD CIRCUMFERENCE (HEADCIRC) -- maximum circumference of the head above the attachment of the ears and ridges of the eyebrows.

63 HEAD LENGTH (HEADLGTH) -- maximum length of the head between the glabella landmark and the opisthocranion.

64 HEEL ANKLE CIRCUMFERENCE (HLAKCIRC) -- circumference of the foot at the ankle and base of the heel.

65 HEEL BREADTH (HEELBRTH) -- maximum horizontal distance between the medial and lateral points on the inside and outside of the heel.

66 HIP BREADTH (HIPBRTH) -- horizontal distance between the hips at the level of the lateral buttock landmarks.

67 HIP BREADTH, SITTING (HIPBRSIT) -- lateral maximum hip or thigh breadth (whichever is broader) of a seated subject.

68 ILIOCRISTALE HEIGHT (ILCRSIT) -- vertical distance between the standing surface and the iliocristale landmark on the top of the right side of the pelvis.

69 INTERPUPILLARY BREADTH (INPUPBTH) -- horizontal distance between the two pupils.

70 INTERSCYE 1 (INSCYE1) -- distance across the back between the top of the right and left axillary fold posterior landmarks.

71 INTERSCYE 2 (INSCYE2) -- distance between the right and left midscye landmarks on the back.

72 KNEE CIRCUMFERENCE (KNEECIRC) -- horizontal circumference of the knee at the level of the midpatella landmark (standing).

73 KNEE HEIGHT, MIDPATELLA (KNEEHTMP) -- vertical distance between the standing surface and the center of the knee at the midpatella landmark.

74 KNEE HEIGHT, SITTING (KNEEHTSI) -- vertical distance between the bottom of the planted foot and the suprapatellar landmark (located standing).

75 LATERAL FEMORAL EPICONDYLE HEIGHT (LATFEMEP) -- vertical distance between the standing surface and the lateral femoral epicondyle landmark on the outside of the knee.

76 LATERAL MALLEOLUS HEIGHT (LATMALHT) -- vertical distance between the standing surface and the lateral malleolus on the outside of the ankle.

77 LOWER THIGH CIRCUMFERENCE (LOTHCIRC) -- horizontal circumference of the thigh at the level of the suprapatellar landmark.

78 MENTON-SELLION LENGTH (MENSELL) -- distance between the menton landmark at the bottom of the chin and the sellion landmark at the deepest point of the nasal root depression.

79 MIDSHOULDER HEIGHT, SITTING (MSHTSIT) -- vertical distance between the sitting surface and the midshoulder landmark at the middle of the top of the right shoulder.

80 NECK-BUSTPOINT/THELION LENGTH (NKBPLGTH) -- distance between the trapezius landmark at the side of the neck and the bustpoint landmark on women or the nipple on men.

81 NECK CIRCUMFERENCE (NECKCIRC) -- circumference of the neck at the infrathyroid landmark (Adam's apple).

82 NECK CIRCUMFERENCE, BASE (NECKCRCB) -- circumference at the base of the neck at the anterior and lateral neck landmarks.

83 NECK HEIGHT, LATERAL (NECKHTLT) -- vertical distance between the standing surface and the trapezius landmark at the side of the neck.

84 OVERHEAD FINGERTIP REACH (OVHDFTRH) -- vertical distance between the standing surface and the tip of the right middle finger when the arms are extended overhead and measured against the wall. The subject stands facing a wall-mounted scale with both arms extended overhead parallel to each other. The toes are 20 cm from the wall and the feet are about 10 cm apart. The palms of the hands rest on the scale. A block is placed against the tip of the finger to establish the measurement. The measurement is taken at the maximum point of quiet respiration.

85 OVERHEAD FINGERTIP REACH, EXTENDED (OVHFRHE) -- vertical distance between the standing surface and the tip of the right middle finger when the arm is extended overhead as high as possible and measured on a wall scale. The subject stands on his/her toes facing a wall-mounted scale with both arms parallel and extended overhead as far as possible. The toes are 20 cm from the wall and the feet are about 10 cm apart. The palms of the hands rest on the scale. A block is placed against the tip of the finger to establish the measurement. The measurement is taken at the maximum point of quiet respiration.

86 OVERHEAD FINGERTIP REACH, SITTING (OVHDFRHS) -- vertical distance between the sitting surface and the tip of the right middle finger when the arm is extended overhead and is measured on a wall scale. The subject sits erect on a flat surface 40.8 cm high with the right arm and hand extended vertically overhead as far as possible and the palm of the hand facing forward Neither the back nor the arm touches the wall. A block placed at the tip of the middle finger spans the distance between the finger and the wall and establishes the measurement on the wall scale. The measurement is made at the maximum point of quiet respiration.

87 POPLITEAL HEIGHT (POPHGHT) -- vertical distance between the foot surface and the bottom of the thigh just behind the knee. The subject is seated with the thighs parallel and the knees flexed 90 degrees.

88 RADIALE-STYLION LENGTH (RASTL) -- distance between the radiale landmark on the elbow and the stylion landmark on the wrist.

89 SCYE CIRCUMFERENCE (SCYECIRC) -- vertical circumference of the upper arm measured with a tape through the armpit passing over the acromion landmark on the tip of the shoulder.

90 SCYE DEPTH (SCYEDPTH) -- vertical surface distance along the spine between the cervicale landmark on the back of the neck and the scye level at midspine landmark.

91 SHOULDER CIRCUMFERENCE (SHOUCIRC) -- horizontal circumference of the shoulders at the level of the maximum protrusion of the right deltoid muscle.

92 SHOULDER-ELBOW LENGTH (SHOUELLT) -- distance between the acromion landmark on the tip of the shoulder and the olecranon landmark at the bottom of the elbow flexed to 90 degrees.

93 SHOULDER LENGTH (SHOULGTH) -- surface distance between the trapezius landmark at the base of the neck and the acromion landmark at the tip of the shoulder.

94 SITTING HEIGHT (SITTHGHT) -- vertical distance between the sitting surface and the top of the head.

95 SLEEVE LENGTH: SPINE-ELBOW (SLLSPEL) -- horizontal surface distance between the midspine landmark and the olecranon center landmark at the tip of the raised elbow. The measurement is made while the arms are held in a horizontal position, parallel to the standing surface, and joined by bringing the fists together.

96 SLEEVE LENGTH: SPINE-SCYE (SLLSPSC) -- horizontal surface distance between the midspine landmark and the posterior-diagonal-scye landmark at the back of the raised right arm. The measurement is made while the arms are held in a horizontal position, parallel to the standing surface, and joined by bringing the fists together.

97 SLEEVE LENGTH: SPINE-WRIST (SLLSPWR) -- horizontal surface distance from the midspine landmark, across the olecranon center landmark at the tip of the elbow to the dorsal wrist landmark. The measurement is made while the arms are held in a horizontal position, parallel to the standing surface, and joined by bringing the fists together.

98 SLEEVE OUTSEAM (SLOUTSM) -- straight-line distance between the acromion landmark on the tip of the shoulder and the stylion landmark on the wrist, measured with the arm is straight at the side and the palm facing forward.

99 SPAN (SPAN) -- distance between the tips of the third fingers when the arms are stretched out horizontally.

100 STATURE (STATURE) -- vertical distance between the standing surface and the top of the head.

101 STRAP LENGTH (STRLGTH) -- distance from the right bustpoint for women or nipple for men over the back of the neck to the left bustpoint or nipple. The tape passes over the left and right lateral neck landmarks.

102 SUPRASTERNALE HEIGHT (SUPSTRHT) -- vertical distance between the standing surface and the suprasternale landmark at the lowest point of the notch at the top of the breastbone.

103 TENTH RIB HEIGHT (TENRIBHT) -- vertical distance between the standing surface and the tenth rib landmark at the bottom of the ribcage.

104 THIGH CIRCUMFERENCE (THGHCIRC) -- circumference of the thigh at its juncture with the buttock.

105 THIGH CLEARANCE (THGHCLR) -- vertical distance between the sitting surface and the highest point on the top of the thigh.

106 THUMB BREADTH (THUMBBR) -- maximum breadth of the thumb perpendicular to its long axis.

107 THUMBTIP REACH (THMBTPR) -- horizontal distance between a wall against which the posterior trunk is in contact and the tip of the thumb when the arm is extended anteriorly.

108 TROCHANTERION* HEIGHT (TROCHHT) -- vertical distance between the standing surface and the trochanterion landmark on the hip.
* In earlier publications also referred to as trochanteric height.

109 VERTICAL TRUNK CIRCUMFERENCE (ASSC)** (VTCASCC) -- vertical circumference of the trunk on a line passing between the buttocks and through the crotch, and over the bustpoint/thelion landmark and midshoulder landmark.
** Aircrew Standardization Committee

110 VERTICAL TRUNK CIRCUMFERENCE (USA)*** (VTCUSA) -- vertical circumference of the trunk on a line passing over the maximum protrusion of the buttocks and through the crotch, and over the bustpoint/thelion landmark and midshoulder landmark.
*** U. S. Army.

111 WAIST BACK LENGTH, NATURAL INDENTATION (WSTBLNI) -- vertical surface distance between the cervicale landmark on the back of the neck and the posterior waist (natural indentation) landmark.

112 WAIST BACK LENGTH, OMPHALION (WSTBLOM) -- vertical surface distance between the cervicale landmark on the back of the neck and the posterior waist landmark at the level of the navel (omphalion).

113 WAIST BREADTH (WSTBRTH) -- horizontal breadth of the waist at the level of the center of the navel (omphalion).

114 WAIST CIRCUMFERENCE, NATURAL INDENTATION (WSCIRCNI) -- horizontal circumference at the level of the natural indentation.

115 WAIST CIRCUMFERENCE, OMPHALION (WSCIRCOM) -- horizontal distance around the torso at the level of the center of the navel (omphalion).

116 WAIST DEPTH (WSTDEPTH) -- horizontal distance between the front and back of the waist at the level of the center of the navel (omphalion).

117 WAIST FRONT LENGTH, NATURAL INDENTATION (WSTFRLNI) -- vertical surface distance between the anterior neck landmark at the front of the neck and the anterior waist (natural indentation).

118 WAIST FRONT LENGTH, OMPHALION (WSTFRLOM) -- vertical surface distance between the anterior neck landmark and center of the navel (omphalion).

119 WAIST HEIGHT, NATURAL INDENTATION (WSTHINI) -- vertical distance between the standing surface and the right natural indentation of the waist.

120 **WAIST HEIGHT, OMPHALION (WSTHOM)** -- vertical distance between the standing surface and the center of the navel (omphalion).

121 **WAIST HEIGHT, SITTING, NATURAL INDENTATION (WSHTSTNI)** -- vertical distance between the sitting surface and the right natural indentation of the waist.

122 **WAIST HEIGHT, SITTING, OMPHALION (WSHTSTOM)** -- vertical distance between the sitting surface and the center of the navel (omphalion).

123 **WAIST-HIP LENGTH (WSHIPLTH)** -- vertical distance between the right waist landmark (omphalion) and the right lateral buttock landmark.

124 **WAIST, NATURAL INDENTATION -- WAIST, OMPHALION LENGTH (WSNIWSOM)** -- surface distance between the right waist (natural indentation) landmark and the right waist (omphalion) landmark.

125 **WEIGHT (WEIGHT)** -- in centigrams (.1 kilograms).

126 **WRIST- CENTER OF GRIP LENGTH (WRCTRGRL)** -- horizontal distance between the stylion landmark on the wrist and the hole in the center of the gripped dowel.

127 **WRIST CIRCUMFERENCE (WRISCIRC)** -- circumference of the wrist perpendicular to the long axis of the forearm at the level of the stylion landmark.

128 **WRIST HEIGHT (WRISHGHT)** -- vertical distance between the standing surface and the stylion landmark on the wrist when the arm is held straight down.

129 **WRIST HEIGHT, SITTING (WRISHTST)** -- vertical distance between the floor and the stylion landmark on the wrist of a seated subject when the arm is held straight down. Note that the seat height used in measuring was 45.5 cm.

130 **WRIST-INDEX FINGER LENGTH (WRINFNGL)** -- distance between the stylion on the wrist and the tip of the index finger.

131 **WRIST-THUMBTIP LENGTH (WRTHLGTH)** -- horizontal distance between the stylion landmark on the wrist and the tip of the thumb.

132 **WRIST-WALL LENGTH (WRWALLEN)** -- horizontal distance between a wall against which the posterior trunk is in contact and the stylion landmark on the wrist when the arm is extended anteriorly and the buttocks and shoulders are against the wall.

133 **WRIST-WALL LENGTH, EXTENDED (WRWALLEX)** -- horizontal distance between a wall against which the posterior trunk is in contact and the stylion landmark on the wrist when the arm is maximally extended and the shoulder is rotated forward and the buttocks and shoulders are against the wall.

Note: The following measurements are illustrated in Visual Index -- Head Measurements, pp. 50-51.

212 BIGONIAL BREADTH HEADBOARD (BIGBRH) -- straight-line distance between the right and left gonion landmarks at the corners of the jaw.

213 BIINFRAORBITAL BREADTH HEADBOARD (BIINORBH) -- straight-line distance between the right and left infraorbitale landmarks at the bottom edge of the bony eye socket.

214 BIOCULAR BREADTH MAXIMUM HEADBOARD (BIOCBRMH) -- straight-line distance between the right and left ectoorbitale landmarks behind each bony eye socket at the level of the outer corners of the eyes.

215 BITRAGION BREADTH HEADBOARD (BTRBDTHH) -- straight-line distance between the right and left tragion landmarks on the cartilaginous flaps in front of each earhole.

216 BIZYGOMATIC BREADTH HEADBOARD (BIZYBRH) -- straight-line distance between the right and left zygion landmarks at the most lateral point of the zygomatic arch.

217 LIP LENGTH HEADBOARD (LIPLGTHH) -- straight-line distance between the right and left cheilion landmarks at the corners of the mouth.

218 MAXIMUM FRONTAL BREADTH HEADBOARD (MAXFRONH) -- straight-line distance between the right and left zygofrontale landmarks at the upper margins of each bony eye socket.

219 MENTON-CRINION LENGTH HEADBOARD (MENCRINH) -- straight-line distance between the menton landmark at the bottom of the chin and the crinion landmark at the lowest point of the hairline on the forehead.

220 MENTON-SELLION LENGTH HEADBOARD (MENSELLH) -- straight-line distance between the menton landmark and the sellion landmark at the deepest point of the nasal root depression.

221 MENTON-SUBNASALE LENGTH HEADBOARD (MENSUBNH) -- straight-line distance between the menton landmark on the bottom of the chin and the subnasale landmark under the nose.

222 MINIMUM FRONTAL BREADTH HEADBOARD (MINFRONH) -- straight-line distance between the right and left frontotemporale landmarks on the temporal crests on each side of the forehead.

223 NOSE BREADTH HEADBOARD (NOSEBRTH) -- straight-line distance between right and left alare landmarks on the sides of the nostrils.

224 NOSE PROTRUSION HEADBOARD (NOSEPRH) -- straight-line distance between the pronasale landmark on the tip of the nose and the subnasale landmark under the nose.

225 SUBNASALE-SELLION HEADBOARD (SBNSSELH) -- straight-line distance between the subnasale landmark under the nose and the sellion landmark at the deepest point of the nasal root depression.

226 ALARE TO BACK OF HEAD (ALAREB) -- horizontal distance between the alare landmark on the side of the nostrils and the vertical plane tangent to the back of the head.

227 ALARE TO TOP OF HEAD (ALARET) -- vertical distance between the alare landmark at the side of the nostril and the horizontal plane tangent to the top of the head.

228 CHEILION TO BACK OF HEAD (CHEILB) -- horizontal distance between the cheilion landmark at the corner of the mouth and the vertical plane tangent to the back of the head.

229 CHEILION TO TOP OF HEAD (CHEILT) -- vertical distance between the cheilion landmark at the corner of the mouth and the horizontal plane tangent to the top of the head.

230 CRINION TO BACK OF HEAD (CRINIONX) -- horizontal distance between the crinion landmark at the lowest point of the hairline on the forehead and the vertical plane tangent to the back of the head.

231 CRINION TO TOP OF HEAD (CRINIONZ) -- vertical distance between the crinion landmark at the lowest point of the hairline on the forehead and the horizontal plane tangent to the top of the head.

232 ECTOORBITALE TO BACK OF HEAD (ECTORBB) -- horizontal distance between the ectoorbitale landmark behind the bony eye socket at the level of the outer corner of the eye and the vertical plane tangent to the back of the head.

233 ECTOORBITALE TO TOP OF HEAD (ECTORBT) -- vertical distance between the ectoorbitale landmark behind the bony eye socket at the level of the outer corner of the eye and the horizontal plane tangent to the top of the head.

234 FRONTOTEMPORALE TO BACK OF HEAD (FRTEMB) -- horizontal distance between the frontotemporale landmark on the temporal crest at the side of the forehead and the vertical plane tangent to the back of the head.

235 FRONTOTEMPORALE TO TOP OF HEAD (FRTEMT) -- vertical distance between the frontotemporale landmark on the temporal crest at the side of the forehead and the horizontal plane tangent to the top of the head.

236 GLABELLA TO BACK OF HEAD (GLABX) -- horizontal distance between the glabella landmark on the forehead between the eyebrows and the vertical plane tangent to the back of the head.

237 GLABELLA TO TOP OF HEAD (GLABZ) -- vertical distance between the glabella landmark on the forehead between the eyebrows and the horizontal plane tangent to the top of the head.

238 GONION TO BACK OF HEAD (GONIONB) -- horizontal distance between the gonion landmark at the corner of the jaw and the vertical plane tangent to the back of the head.

239 GONION TO TOP OF HEAD (GONIONT) -- vertical distance between the gonion landmark at the corner of the jaw and the horizontal plane tangent to the top of the head.

240 INFRAORBITALE TO BACK OF HEAD (INFORBB) -- horizontal distance between the infraorbitale landmark on the bony eye socket under the eye and the vertical plane tangent to the back of the head.

241 INFRAORBITALE TO TOP OF HEAD (INFORBT) -- vertical distance between the infraorbitale landmark on the bony eye socket under the eye and the horizontal plane tangent to the top of the head.

242 MENTON TO BACK OF HEAD (MENTONX) -- horizontal distance between the menton landmark at the bottom of the chin and the vertical plane tangent to the back of the head.

243 MENTON TO TOP OF HEAD (MENTONZ) -- vertical distance between the menton landmark at the bottom of the chin and the horizontal plane tangent to the top of the head.

244 PROMENTON TO BACK OF HEAD (PMENTONX) -- horizontal distance between the promenton landmark at the chin and the vertical plane tangent to the back of the head.

245 PROMENTON TO TOP OF HEAD (PMENTONZ) - vertical distance between the promenton landmark at the chin and the horizontal plane tangent to the top of the head.

246 PRONASALE TO BACK OF HEAD (PRONASX) -- horizontal distance between the pronasale landmark at the tip of the nose and the vertical plane tangent to the back of the head.

247 PRONASALE TO TOP OF HEAD (PRONASZ) -- vertical distance between the pronasale landmark at the tip of the nose and the horizontal plane tangent to the top of the head.

248 SELLION TO BACK OF HEAD (SELLIONX) -- horizontal distance between the sellion landmark at the deepest point of the nasal root depression and the vertical plane tangent to the back of the head.

249 SELLION TO TOP OF HEAD (SELLIONZ) -- vertical distance between the sellion landmark at the deepest point of the nasal root depression and the horizontal plane tangent to the top of the head.

250 STOMION TO BACK OF HEAD (STOMIONX) -- horizontal distance between the stomion landmark at the center of the mouth in the midsagittal plane and the vertical plane tangent to the back of the head.

251 STOMION TO TOP OF HEAD (STOMIONZ) -- vertical distance between the stomion landmark at the center of the mouth in the midsagittal plane and the horizontal plane tangent to the top of the head.

252 SUBNASALE TO BACK OF HEAD (SUBNASX) -- horizontal distance between the subnasale landmark under the nose and the vertical plane tangent to the back of the head.

253 SUBNASALE TO TOP OF HEAD (SUBNASZ) -- vertical distance between the subnasale landmark under the nose and the horizontal plane tangent to the top of the head.

254 TRAGION TO BACK OF HEAD (TRAGB) -- horizontal distance between the tragion landmark on the cartilaginous flap in front of the earhole and the vertical plane tangent to the back of the head.

255 TRAGION TO TOP OF HEAD (TRAGT) -- vertical distance between the tragion landmark on the cartilaginous flap in front of the earhole and the horizontal plane tangent to the top of the head.

256 ZYGION TO BACK OF HEAD (ZYGB) -- horizontal distance between the zygion landmark on the zygomatic arch and the vertical plane tangent to the back of the head.

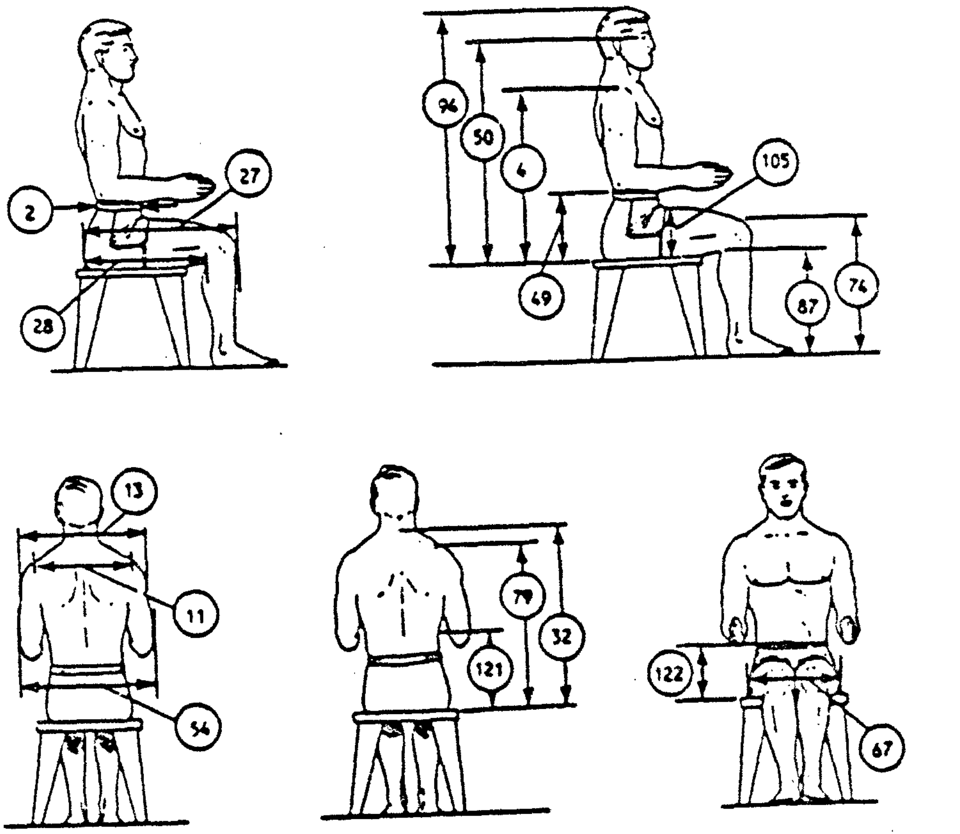
257 ZYGION TO TOP OF HEAD (ZYGT) -- vertical distance between the zygion landmark on the zygomatic arch and the horizontal plane tangent to the top of the head.

258 ZYGOFRONTALE TO BACK OF HEAD (ZYFRB) -- horizontal distance between the zygofrontale landmark at the upper margin of the bony eye socket and the vertical plane tangent to the back of the head.

259 ZYGOFRONTALE TO TOP OF HEAD (ZYFRT) -- vertical distance between the zygofrontale landmark at the upper margin of the bony eye socket and the horizontal plane tangent to the top of the head.

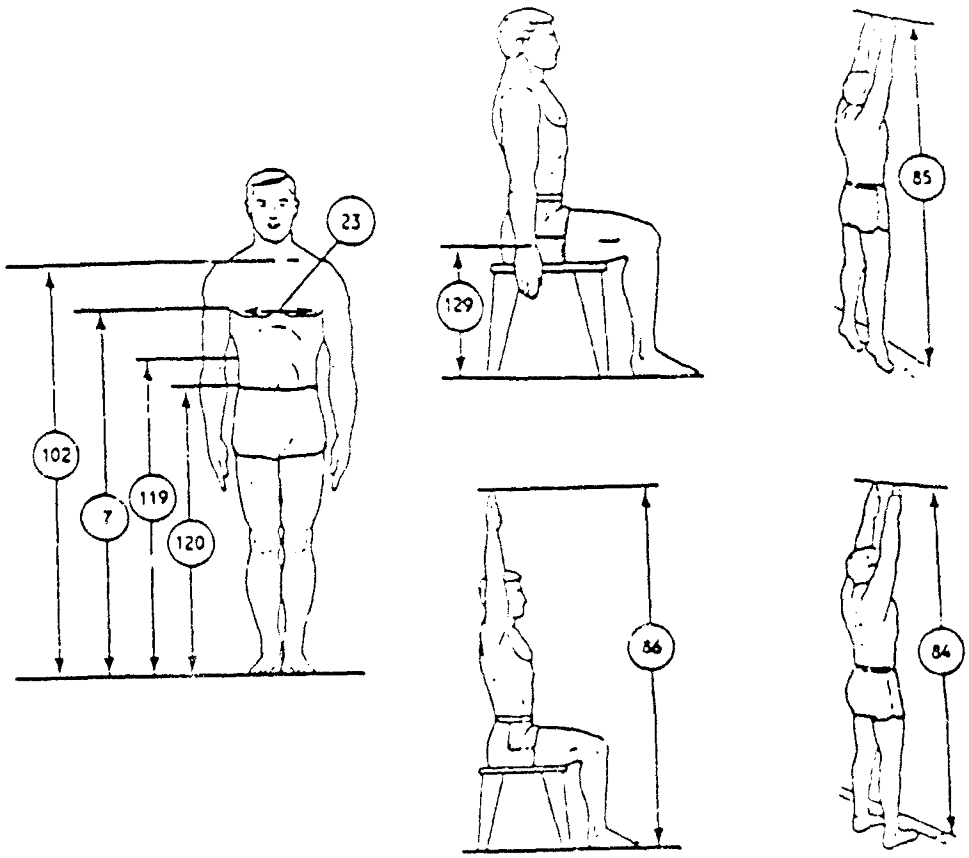
302 AGE (AGE) -- chronological age in years.

VISUAL INDEX - THE STANDARD MEASUREMENTS



(2) ABDOMINAL EXTENSION DEPTH SITTING
(4) ACROMIAL HEIGHT SITTING
(11) BIACROMIAL BREADTH
(13) BIDELTOID BREADTH
(27) BUTTOCK-KNEE LENGTH
(28) BUTTOCK-POPLITEAL LENGTH
(32) CERVICALE HEIGHT SITTING
(49) ELBOW REST HEIGHT
(50) EYE HEIGHT SITTING
(54) FOREARM-FOREARM BREADTH
(67) HIP BREADTH SITTING
(74) KNEE HEIGHT SITTING
(79) MIDSHOULDER HEIGHT SITTING
(87) POPLITEAL HEIGHT
(94) SITTING HEIGHT
(105) THIGH CLEARANCE
(121) WAIST HEIGHT SITTING, NATURAL INDENTATION
(122) WAIST HEIGHT SITTING, OMPHALION

VISUAL INDEX - THE STANDARD MEASUREMENTS (Continued)



(7) AXILLA HEIGHT

(23) BUSTPOINT/THELION-BUSTPOINT/THELION BREADTH

(84) OVERHEAD FINGERTIP REACH

(85) OVERHEAD FINGERTIP REACH EXTENDED

(86) OVERHEAD FINGERTIP REACH SITTING

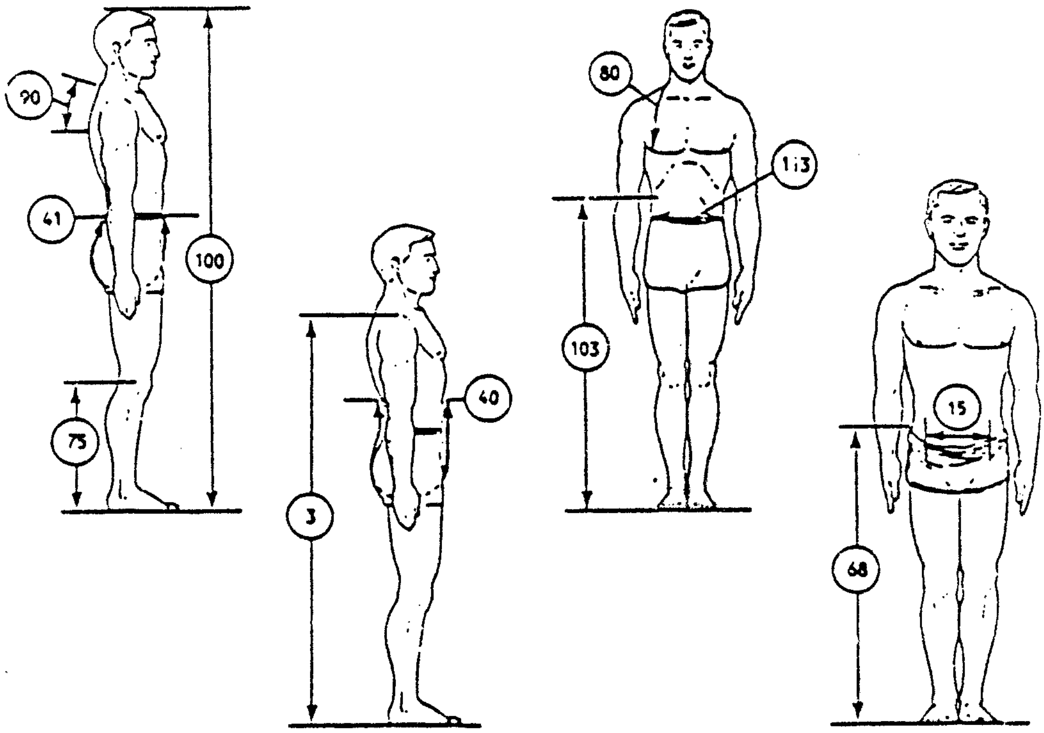
(102) SUPRASTERNALE HEIGHT

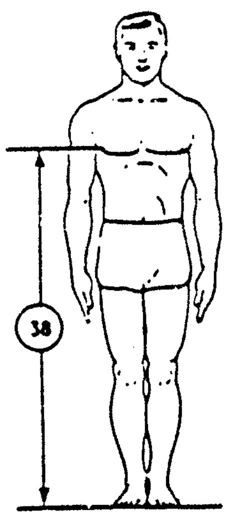
(119) WAIST HEIGHT, NATURAL INDENTATION

(120) WAIST HEIGHT, OMPHALION

(129) WRIST HEIGHT SITTING

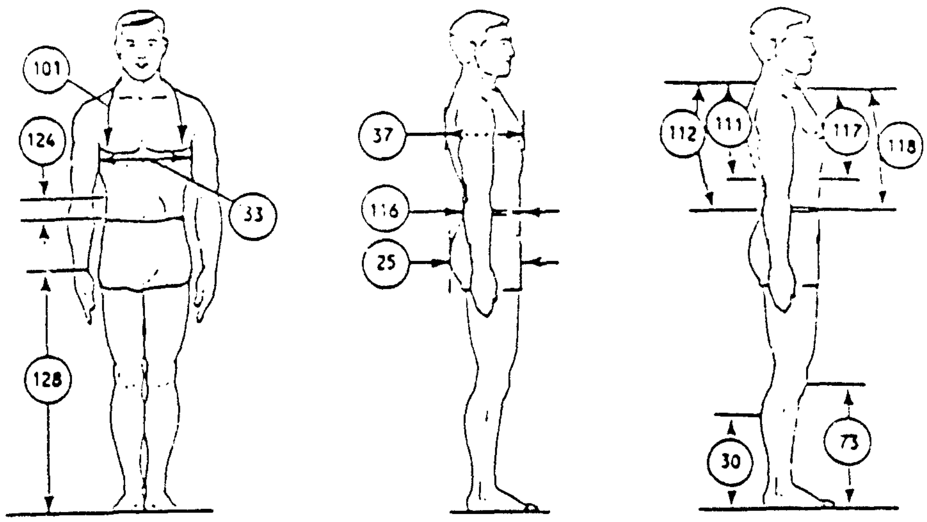
VISUAL INDEX - THE STANDARD MEASUREMENTS (Continued)

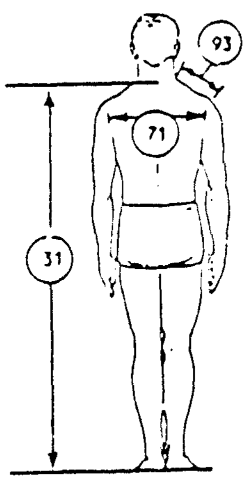




(3) ACROMIAL HEIGHT
(15) BISPINOUS BREADTH
(38) CHEST HEIGHT
(40) CROTCH LENGTH, NATURAL INDENTATION
(41) CROTCH LENGTH, OMPHALION
(68) ILIOCRISTALE HEIGHT
(75) LATERAL FEMORAL EPICONDYLE HEIGHT
(80) NECK-BUSTPOINT/THELION LENGTH
(90) SCYE DEPTH
(100) STATURE
(103) TENTH RIB HEIGHT
(113) WAIST BREADTH

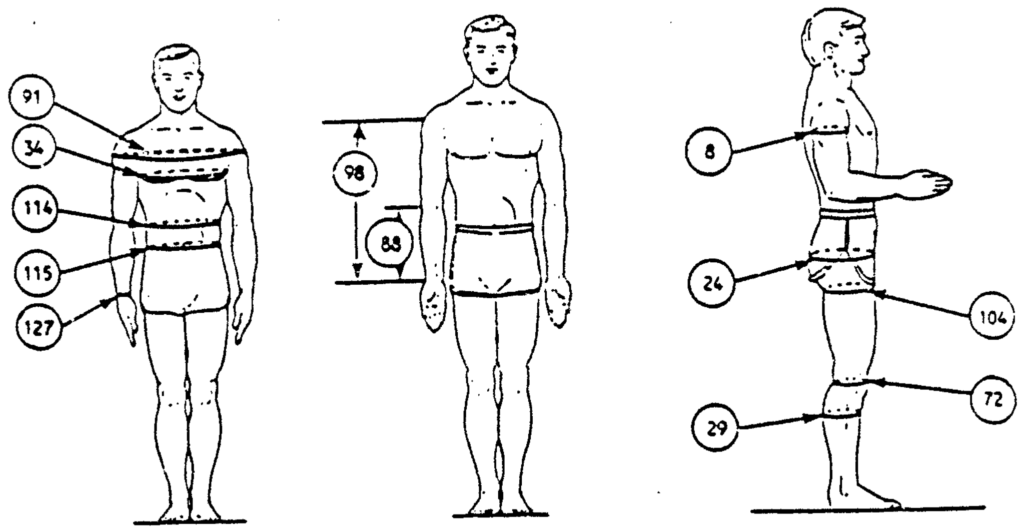
VISUAL INDEX - THE STANDARD MEASUREMENTS (Continued)

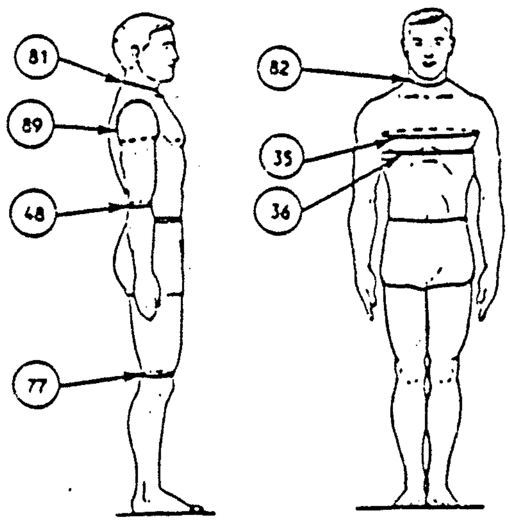




(25) BUTTOCK DEPTH
(30) CALF HEIGHT
(31) CERVICALE HEIGHT
(33) CHEST BREADTH
(37) CHEST DEPTH
(71) INTERSCYE 2
(73) KNEE HEIGHT MIDPATELLA
(93) SHOULDER LENGTH
(101) STRAP LENGTH
(111) WAIST BACK LENGTH, NATURAL INDENTATION
(112) WAIST BACK LENGTH, OMPHALION
(116) WAIST DEPTH
(117) WAIST FRONT LENGTH, NATURAL INDENTATION
(118) WAIST FRONT LENGTH, OMPHALION
(124) WAIST, NATURAL INDENTATION - WAIST, OMPHALION LENGTH
(128) WRIST HEIGHT

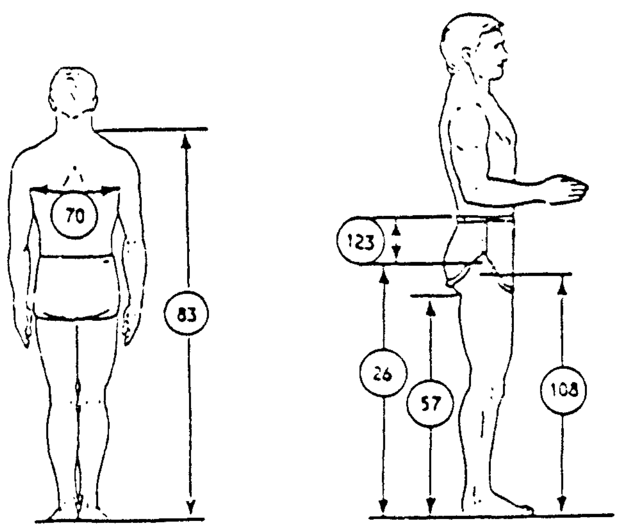
VISUAL INDEX - THE STANDARD MEASUREMENTS (Continued)

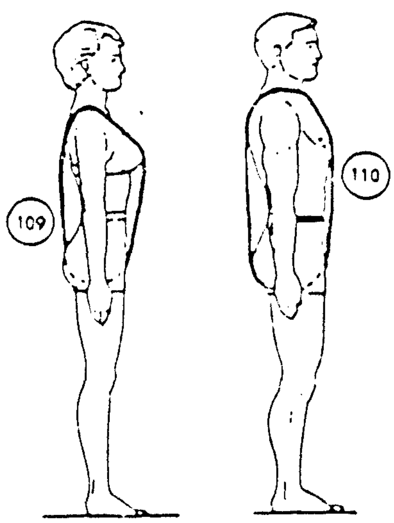


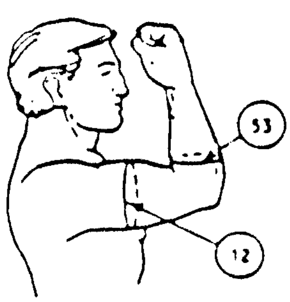


(8) AXILLARY ARM CIRCUMFERENCE
(24) BUTTOCK CIRCUMFERENCE
(29) CALF CIRCUMFERENCE
(35) CHEST CIRCUMFERENCE AT SCYE
(34) CHEST CIRCUMFERENCE
(36) CHEST CIRCUMFERENCE BELOW BREAST
(48) ELBOW CIRCUMFERENCE
(72) KNEE CIRCUMFERENCE
(77) LOWER THIGH CIRCUMFERENCE
(81) NECK CIRCUMFERENCE
(82) NECK CIRCUMFERENCE BASE
(88) RADIALE-STYLION LENGTH
(89) SCYE CIRCUMFERENCE
(91) SHOULDER CIRCUMFERENCE
(98) SLEEVE OUTSEAM
(104) THIGH CIRCUMFERENCE
(114) WAIST CIRCUMFERENCE, NATURAL INDENTATION
(115) WAIST CIRCUMFERENCE, OMPHALION
(127) WRIST CIRCUMFERENCE

VISUAL INDEX - THE STANDARD MEASUREMENTS (Continued)

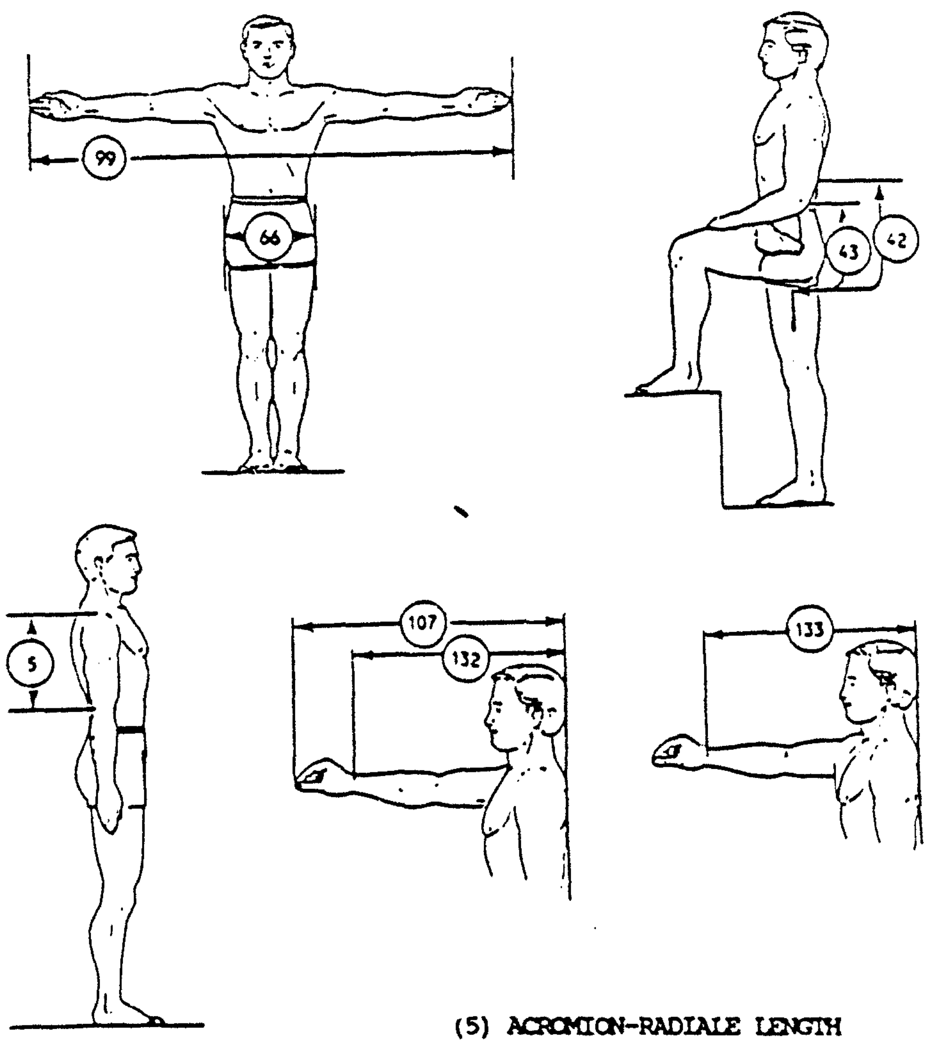


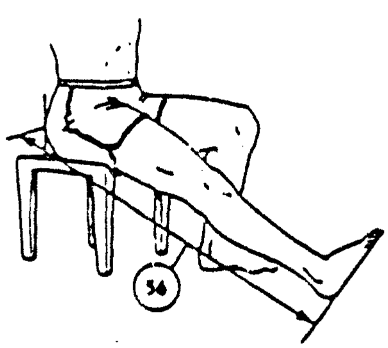




(12) BICEPS CIRCUMFERENCE FLEXED
(26) BUTTOCK HEIGHT
(39) CROTCH HEIGHT
(53) FOREARM CIRCUMFERENCE FLEXED
(55) FOREARM-HAND LENGTH
(57) GLUTEAL FURROW HEIGHT
(70) INTERSCYE 1
(83) NECK HEIGHT LATERAL
(92) SHOULDER-ELBOW LENGTH
(108) TROCHANTERION HEIGHT
(109) VERTICAL TRUNK CIRCUMFERENCE (ASCC)
(110) VERTICAL TRUNK CIRCUMFERENCE (USA)
(123) WAIST-HIP LENGTH

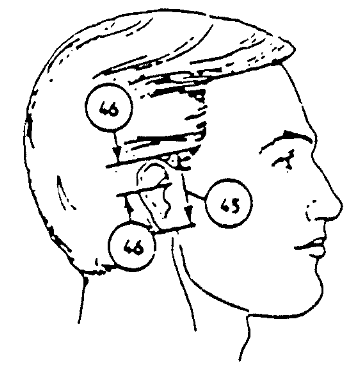
VISUAL INDEX - THE STANDARD MEASUREMENTS (Continued)

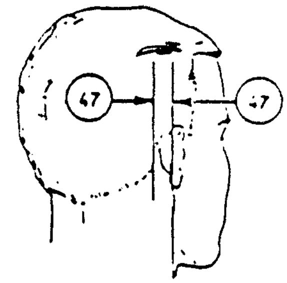


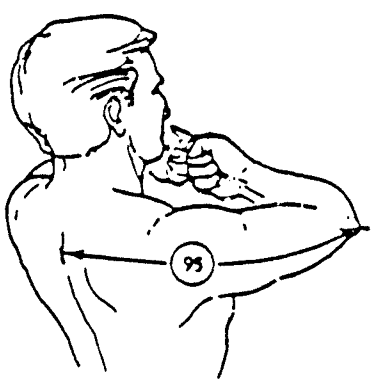


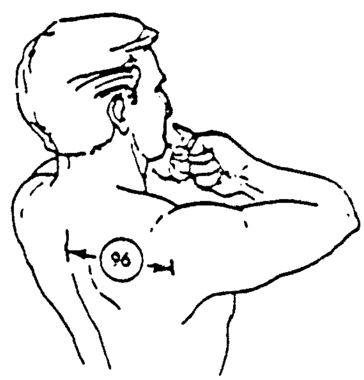
(5) ACROMION-RADIALE LENGTH
(42) CROTCH LENGTH POSTERIOR, NATURAL INDENTATION
(43) CROTCH LENGTH POSTERIOR, OMPHALION
(56) FUNCTIONAL LEG LENGTH
(66) HIP BREADTH
(99) SPAN
(107) THUMBTIP REACH
(132) WRIST-WALL LENGTH
(133) WRIST-WALL LENGTH EXTENDED

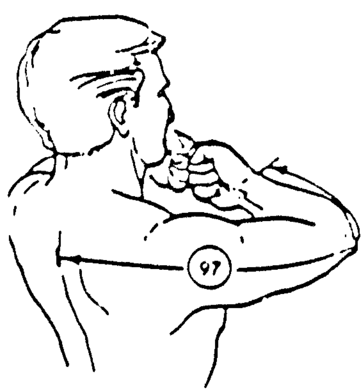
VISUAL INDEX - THE STANDARD MEASUREMENTS (Continued)











(45) EAR LENGTH

(46) EAR LENGTH ABOVE TRAGION

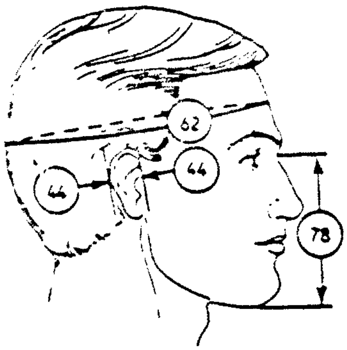
(47) EAR PROTRUSION

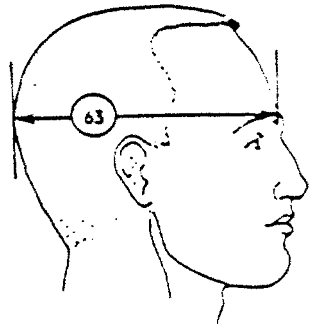
(95) SLEEVE LENGTH: SPINE-ELBOW

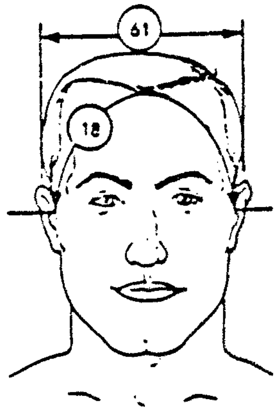
(96) SLEEVE LENGTH: SPINE-SCYE

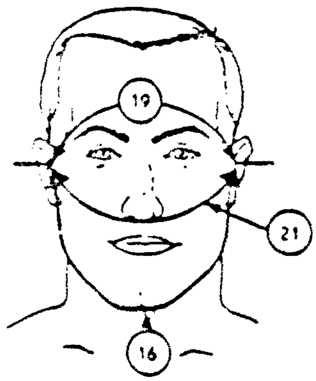
(97) SLEEVE LENGTH: SPINE-WRIST

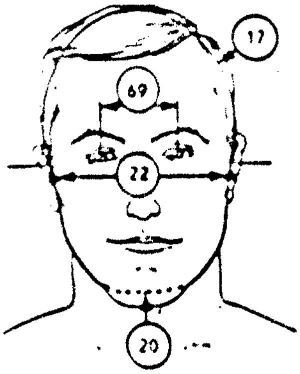
VISUAL INDEX - THE STANDARD MEASUREMENTS (Continued)





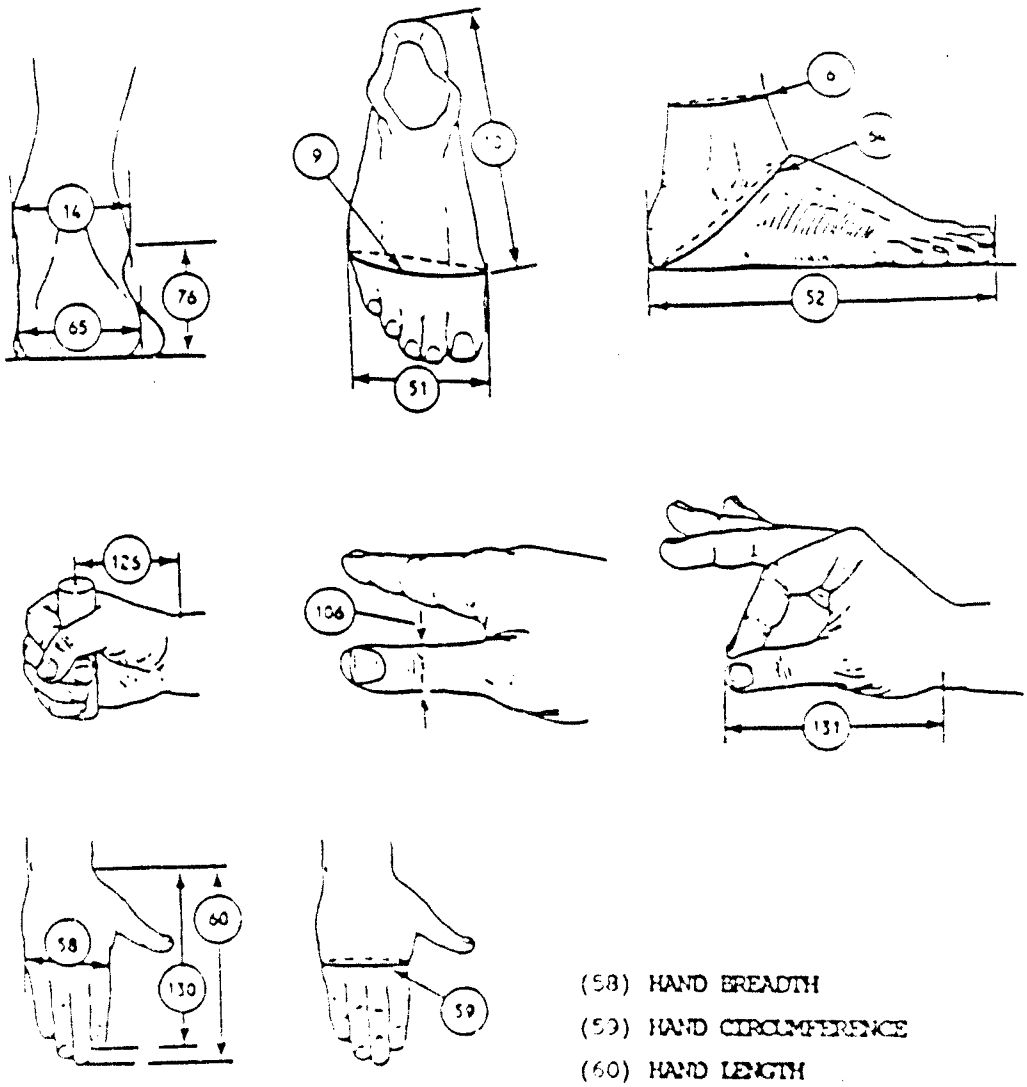






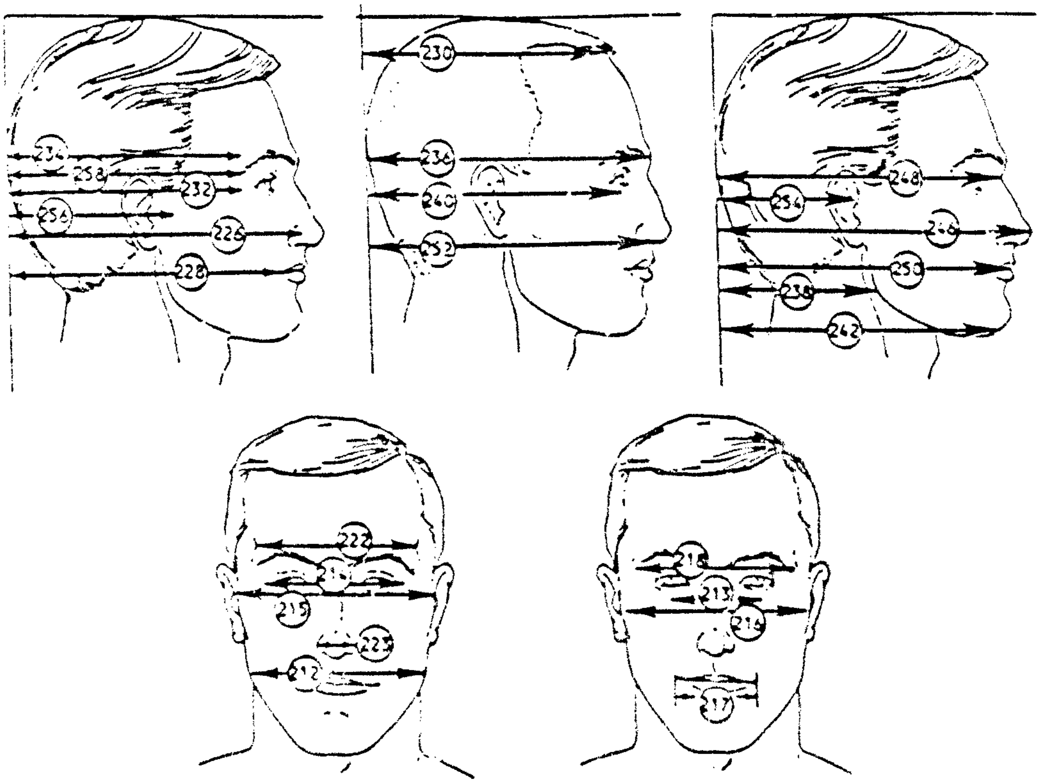
(16) BITRAGION CHIN ARC
(17) BITRAGION CORONAL ARC
(18) BITRAGION CRINION ARC
(19) BITRAGION FRONTAL ARC
(20) BITRAGION SUBMANDIBULAR ARC
(21) BITRAGION SUBNASALE ARC
(22) BIZYGOMATIC BREADTH
(44) EAR BREADTH
(61) HEAD BREADTH
(62) HEAD CIRCUMFERENCE
(63) HEAD LENGTH
(69) INTERPUPILLARY BREADTH
(78) MENTON-SELLION LENGTH

VISUAL INDEX - THE STANDARD MEASUREMENTS (Continued)



(6) ANKLE CIRCUMFERENCE
(9) BALL OF FOOT CIRCUMFERENCE
(10) BALL OF FOOT LENGTH
(14) BIMALLEOLAR BREADTH
(51) FOOT BREADTH HORIZONTAL
(52) FOOT LENGTH
(58) HAND BREADTH
(59) HAND CIRCUMFERENCE
(60) HAND LENGTH
(64) HEEL ANKLE CIRCUMFERENCE
(65) HEEL BREADTH
(76) LATERAL MALLEOLUS HEIGHT
(106) THUMB BREADTH
(126) WRIST-CENTER OF GRIP LENGTH
(130) WRIST-INDEX FINGER LENGTH
(131) WRIST-THUMBTIP LENGTH

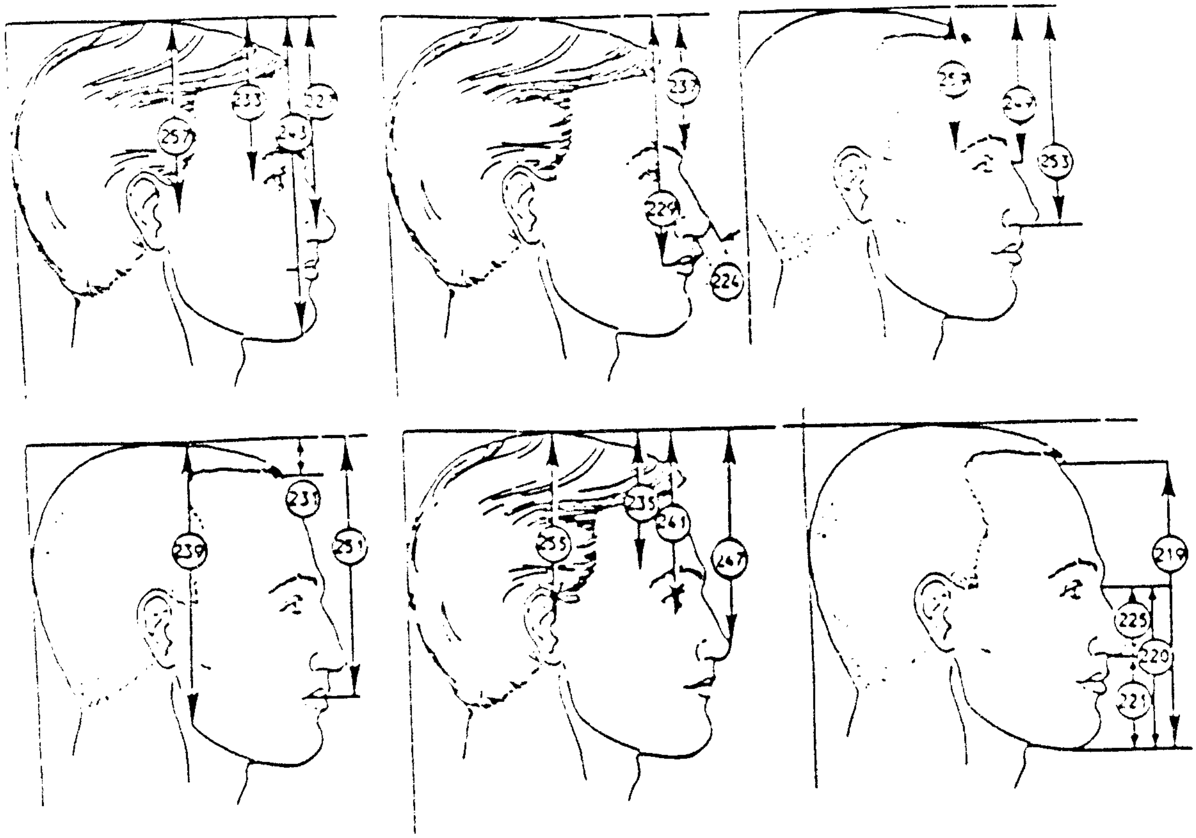
VISUAL INDEX - HEAD MEASUREMENTS



(226) ALARE TO BACK OF HEAD
(212) BIGONIAL BREADTH HEADBOARD
(213) BIINFRAORBITALE BREADTH HEADBOARD
(214) BIOCULAR BREADTH MAXIMUM HEADBOARD
(215) BITRAGION BREADTH HEADBOARD
(216) BIZYGOMATIC BREADTH HEADBOARD
(228) CHEILION TO BACK OF HEAD
(230) CRINION TO BACK OF HEAD
(232) ECTOORBITALE TO BACK OF HEAD
(234) FRONTOTEMPORALE TO BACK OF HEAD
(236) GLABELLA TO BACK OF HEAD
(238) GONION TO BACK OF HEAD
(240) INFRAORBITALE TO BACK OF HEAD

(217) LIP LENGTH HEADBOARD
(218) MAXIMUM FRONTAL BREADTH HEADBOARD
(242) MENTON TO BACK OF HEAD
(222) MINIMUM FRONTAL BREADTH HEADBOARD
(223) NOSE BREADTH
(246) PRONASALE TO BACK OF HEAD
(248) SELLION TO BACK OF HEAD
(250) STOMION TO BACK OF HEAD
(252) SUBNASALE TO BACK OF HEAD
(254) TRAGION TO BACK OF HEAD
(256) ZYGION TO BACK OF HEAD
(258) ZYGOFRONTALE TO BACK OF HEAD

VISUAL INDEX - HEAD MEASUREMENTS (Continued)



(227) ALARE TO TOP OF HEAD
(229) CHEILION TO TOP OF HEAD
(231) CRINION TO TOP OF HEAD
(233) ECTOORBITALE TO TOP OF HEAD
(235) FRONTOTEMPORALE TO TOP OF HEAD
(237) GLABELLA TO TOP OF HEAD
(239) GONION TO TOP OF HEAD
(241) INFRAORBITALE TO TOP OF HEAD
(219) MENTON-CRINION LENGTH HEADBOARD
(220) MENTON-SELLION LENGTH HEADBOARD
(221) MENTON-SUBNASALE LENGTH HEADBOARD
(243) MENTON TO TOP OF HEAD
(224) NOSE PROTRUSION HEADBOARD
(247) PRONASALE TO TOP OF HEAD
(249) SELLION TO TOP OF HEAD
(251) STOMION TO TOP OF HEAD
(225) SUBNASALE TO SELLION LENGTH
(253) SUBNASALE TO TOP OF HEAD
(255) TRAGION TO TOP OF HEAD
(257) ZYGION TO TOP OF HEAD
(259) ZYGOFRONTALE TO TOP OF HEAD

INDEX

Entries in capital letters are anthropometric measurements and those in mixed capital and lower case letters represent landmarks on the body. All measurements given in the index have pages identified in a particular order. The first page number is for the measurement definition followed by the Visual Index, the male bivariate regression table, the female bivariate regression table, the male stepwise regression table, and the female stepwise regression table. Any additional entries are for the standard multiple regression tables. Only dependent variables are indexed for the bivariate and stepwise regression tables while both dependent and independent variables are identified in the standard multiple regression tables. Entries are not provided for the correlation tables since each variable appears on every third page in each of the 10 tables.

Part 1 of this series is pp. 1 - 51; Part 2 is pp. 52 - 312; Part 3 is pp. 313 - 572; Part 4 is pp. 573 - 853; Part 5 is pp. 854 - 984.

This document reports research undertaken at the US Army Natick Research, Development and Engineering Center and has been assigned No. NATICK/TR-[illegible] in the series of reports approved for publication.

AD-A224 986

ERRATA

TITLE:	1988 Anthropometric Survey of U.S. Army Personnel: Correlation Coefficients and Regression Equations Parts 1 through 5.
AUTHORS:	James Cheverud, Claire C. Gordon, Robert A. Walker, Cashell Jacquish, Luci Kohn, Allen Moore, and Nyuta Yamashita
TECHNICAL REPORTS:	Natick/TR-90/032, TR-90/033, TR-90/034, TR-90/035, and TR-90/036
AD NUMBER:	A224 986, A224 987, A224 988, A224 989, A224 990
Publication Year:	May 1990

For the above-referenced Technical Reports, note should be made that head and face dimensions measured with the automated headboard device were recorded to the nearest 0.1 millimeter, not to the nearest millimeter as indicated originally on page 25 of Part I. Conversion procedures are outlined on the following page.

When calculating regressions using headboard dimensions, conversions from 0.1 mm to 1 mm are necessary:

1) When . . .

   Headboard dimension = dependent variable
   Standard dimension = independent variable

   divide the answer by 10.

   <u>e.g.</u> <u>Glabx by Headcirc</u>

   x=(3.862 * 567.7) + (-195.529)
   y=1996.9284 / 10
   x=199.7 mm

   [Note: When Headboard dimension is the dependent variable, the Standard Estimate of Error is in 0.1 mm.]

2) When . . .

   Headboard dimension = independent variable
   Standard dimension = dependent variable

   multiply headboard input by 10.

   <u>e.g.</u> <u>Headcirc by Glabx</u>

   y=199.7 * 10
   x=(.176 * 1997) + 215.654
   x=567.1 mm

3) When . . .

   Headboard dimension = independent variable
   Headboard dimension = dependent variable

   multiply headboard input by 10;
   divide answer by 10.

   <u>e.g.</u> <u>Glabx by Subnas</u>

   y=203.5 * 10
   x=(.704 * 2035) + 564.589
   x=1997.229 / 10
   x=199.7 mm