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Anthropometric estimates for Colombian adults

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Miami, Florida

ANTHROPOMETRIC ESTIMATES FOR COLOMBIAN ADULTS

A thesis submitted in partial satisfaction of the

requirements for the degree of

MASTER OF SCIENCE

IN

INDUSTRIAL ENGINEERING

by

Orlando A. Corredor

1994

To: Gordon R. Hopkins
    Engineering and Design

This thesis, written by Orlando A. Corredor, and entitled ANTHROPOMETRIC ESTIMATES FOR COLOMBIAN ADULTS, having been approved in respect to style and intellectual content, is referred to you for judgement.

We have read this thesis and recommend that it be approved.

Chin Sheng Chen

German Nunez

Mark L. Resnick, Major Professor

December 2, 1994:

The thesis of Orlando A. Corredor is approved.

Dean Gordon R. Hopkins
College of Engineering and Design

Dr. Richard L. Campbell
Dean of Graduate Studies

Florida International University, 1994

This thesis is dedicated to my family and friends who have patiently given me their

support during the preparation of this study.

ACKNOWLEDGMENTS

ABSTRACT OF THE THESIS

ANTHROPOMETRIC ESTIMATES FOR COLOMBIAN ADULTS

by

Orlando A. Corredor

Florida International University, 1994

Miami, Florida

Professor Marc Resnick, Major Professor

Knowledge of anthropometric dimensions is important for the design of workspaces and equipment. In a developing country, such as Colombia, no anthropometric survey for Colombian adults has yet been published. Therefore, the purpose of this study is to assemble a Colombian adult anthropometric data set sufficiently accurate for design applications. An anthropometric survey was conducted on 134 Colombian adults living in South Florida. Twenty body dimensions were measured. Moreover, an anthropometric estimation method was selected, described and validated to be used as a reference when measurement of the user population is not possible. Anthropometric estimates, using the scaling ratio method, and those obtained in the survey were analyzed and compared with other population data. Tables are assembled and dimensional models are suggested which may be used as a design tool.

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CHAPTER I - INTRODUCTION

The goal of engineering anthropometry is to obtain a set of physical measurements that accurately describe the user population. It is essential that the sample be truly representative of the population and the designer be aware of the population from which the data are taken. Therefore, ergonomists are often called to supply designers with anthropometric data of different sexes, ages, races and nationalities. Because of the great variety of people within different ethnicities, the generalizability of anthropometric data measured from a single group is very limited. However, measuring every dimension of every ethnic group would be costly and a prohibitively time consuming task. This tradeoff commonly presents problems for ergonomists and designers; consequently, they are frequently forced to prepare anthropometric tables based on estimations rather than on measurement.

Everywhere, knowledge of anthropometric dimensions for user populations has become a critical requisite in the design of products, machines, furniture, clothing, work places, etc. In a developing country such as Colombia, where industrial growth is rapidly progressing, no anthropometric survey sufficiently comprehensive for practical purposes has yet been published. The most significant contribution has been a survey of stature and weight conducted by The Colombian Ministry of Public Health. (MINSALUD, 1980).

Consequently, designers, engineers, physicians and architects have to rely on anthropometric data from American and European populations since these are virtually the only available sources. Currently, the Colombian industry is in the process of modernization, and some of the systems used are produced locally, such as home and office furniture, clothes, hand tools, even car assembly, in addition to a wide variety of consumable items. However, heavy machines, military equipment, automobiles, control rooms, personal computers and other sophisticated systems are mainly imported from the U.S., Europe, and Japan, and most of them were not designed to fit the Colombian user. Consequently, the utilization of these products and equipment tends to cause operational difficulties, job related fatigue, injuries, lower productivity and other design related problems.

An anthropometric survey was therefore carried out on 134 Colombian adults living in South Florida. Twenty functional dimensions were measured. In addition, an anthropometric data estimation method was selected, described and validated to be used as a reference when measurement of user population will not be possible. Roebuck, Kromer, and Thomson (1975) and Pheasant (1988) have listed several techniques for data estimation; some of them are: correlations, regressions, sum and difference of dimensions, scaling ratio, etc. The Scaling Ratio Method used by Barkla (1961), in which the parameters (i.e. mean and standard deviation) of unknown variables are scaled from those

of stature was selected as a reference estimation method..

The main objective of this study was to analyze, discuss and compare, with other populations, the survey and estimation method findings, and to assemble a Colombian adult anthropometric data set which will be sufficiently comprehensive, accurate and useful for general design applications.

CHAPTER II - ANTHROPOMETRIC SURVEY

1- LITERATURE REVIEW.

1.1- COLOMBIAN ANTHROPOMETRIC STUDIES.

In Colombia, anthropometric data are scarce. Unfortunately, no anthropometric survey sufficiently extensive for practical applications has yet been published. The most significant contribution to the subject has been a survey of stature and weight conducted by The Colombian Ministry of Public Health. (MINSALUD) in 1980. The sample was chosen to be representative of the general population in terms of age and geographical distribution. Moreover, several surveys concerned with the Colombian population have been published, but these studies were limited to demographic rather than anthropometric variables.

2- SUBJECTS.

2.1- TARGET POPULATION.

South Americans have traditionally been the least likely among the Latin Americans to emigrate to The United States. Lately their number have increased substantially, led by the Colombians, followed by Ecuadorians and Peruvians. Currently, more than a million South Americans live in The United States. Table 1 shows the largest Hispanic groups by

4

national origins in U.S.

According to the 1990 U.S. Census, 378,726 Colombians live in the United States; 83,643 (22%) of them live in Florida and 53,582 (14.2%) live in Dade County. In addition, an indeterminate number of Colombian immigrants have arrived in Florida in the last 4 years. For this reason, the Colombian population living in South Florida was considered as a representative sample of the general Colombian population, and was taken as a reference target population to conduct this anthropometric survey.

2.2- SAMPLE SIZE DETERMINATION.

In an anthropometric survey it is usually impossible or economically undesirable to measure every individual in the target population. Instead a representative group of individuals is selected from the target population. The selected sample must be large enough to assure the accuracy and representiveness of the results while being small enough for the survey to stay within economic constraints (Roebuck et al. 1975).

Anthropometric data are usually distributed in a reasonably normal Gaussian distribution. Hence in this study, estimation of the required sample size was conducted using the regular parametric statistics method. In this method, calculations are done using: (a) an estimate of the dispersion or variability of the dimension that will be measured or used as a reference, (b) a required level of accuracy of the final results, and (c) the desired

Table 1

Largest Hispanic Groups by National Origins in U.S. (1990)

	Country	Population
1-	Mexico	13,393,208
2-	Puerto Rico	2,651,615
3-	Cuba	1,053,197
4-	Salvador	565,081
5-	Dominican R.	520,151
6-	**Colombia**	**378,726**
7-	Guatemala	268,779
8-	Nicaragua	202,658
9-	Ecuador	191,196
10-	Peru	175,035
11-	Honduras	131,066
12-	Argentina	100,921
	TOTAL	**19,631,633**

confidence coefficient.

Assuming normal distribution of the measured variable, the required sample size (N) can be estimated from the following formula:

$$N = [(K * SD) / d]^2.$$

Where:

N = Sample size required.

SD = Estimated standard deviation of data.

d = The desired accuracy of the measurement, how close we wish our estimate to be to the true value of the population parameter (d units).

K = Statistical value on the standard normal distribution for the confidence limit of interest (see Table 2), how certain we wish to be that our estimate will be within the selected number of units of the value of the parameter.

2.2.1- POPULATION DIMENSION VARIABILITY ESTIMATION.

Taking into consideration the dimensions selected for this study and those reported in other anthropometric surveys, stature, was selected as a reference dimension, to be used in

Table 2

K Values for Sample Size Determination

Statistical value K	Confidence Limit %
1.96	95
1.65	90
1.15	75
1.04	70

the sample size calculation, due to its design relevance and its statistical characteristics (normal frequency distribution, variability value and lowest coefficient of variation).

In order to obtain an accurate estimated value of the reference dimension's standard deviation, a small pilot study was conducted. In this study 20 Colombian adults, 10 male and 10 female, were randomly selected and measured using the procedures described in Appendix A. Results showed a standard deviation of 59 mm.

2.2.2- ACCURACY AND CONFIDENCE LEVEL.

In the design process, the range of a dimension within the user population which is of interest is generally between the 5th percentile female value and the 95th percentile male value. This ensures accommodation of at least 90 percent of the population. Therefore, the accuracy of estimates of the 5th or 95th percentile values should be at least as good as the accuracy of an individual measurement.

Taking into consideration the statistical parameters of the dimension selected as a reference and the results of the Stature Measurement Reliability Tests, it was decided therefore to use an accuracy level of 10 millimeters with a confidence limit of 95 percent in the sample size calculation.

2.2.3- SAMPLE SIZE CALCULATION.

Sample size was determined using "Stature" as a reference dimension, with a standard deviation of 59.0 millimeters, a level of accuracy of 10 millimeters, and a confidence level of 95%. The results, included in Appendix B, showed that the minimum sample size required to achieve the desired degree of precision was 134 people.

With this sample size, the standard error of the 5 or 95 percentile partition value was equal to the measurement accuracy; therefore, 134 subjects was regarded as an adequate sample size for the survey.

2.2.4- SAMPLE STRATIFICATION.

In order to enable our measurement data to be applicable to the total Colombian adult population, the required sample size (134 subjects) was stratified according to a height distribution which came from the stature's statistics reported by MINSALUD in 1980.

In addition, the country was divided into 6 geographical regions: Atlantic, Bogota, Central, Oriental, Pacific and others, (see Figure 1). Required sample size for each height interval was then chosen according to the population's sex percentage in each region. Eight subjects that could not be recruitment from a determinate region were replaced by others with similar stature characteristics, but from other regions, in order to maintain the height interval required. Table 3 shows the stratified composition of the required sample size.

Figure 1. Colombian Geographical Division.

Atlantic
Bogota
Central
Oriental
Pacific
Others
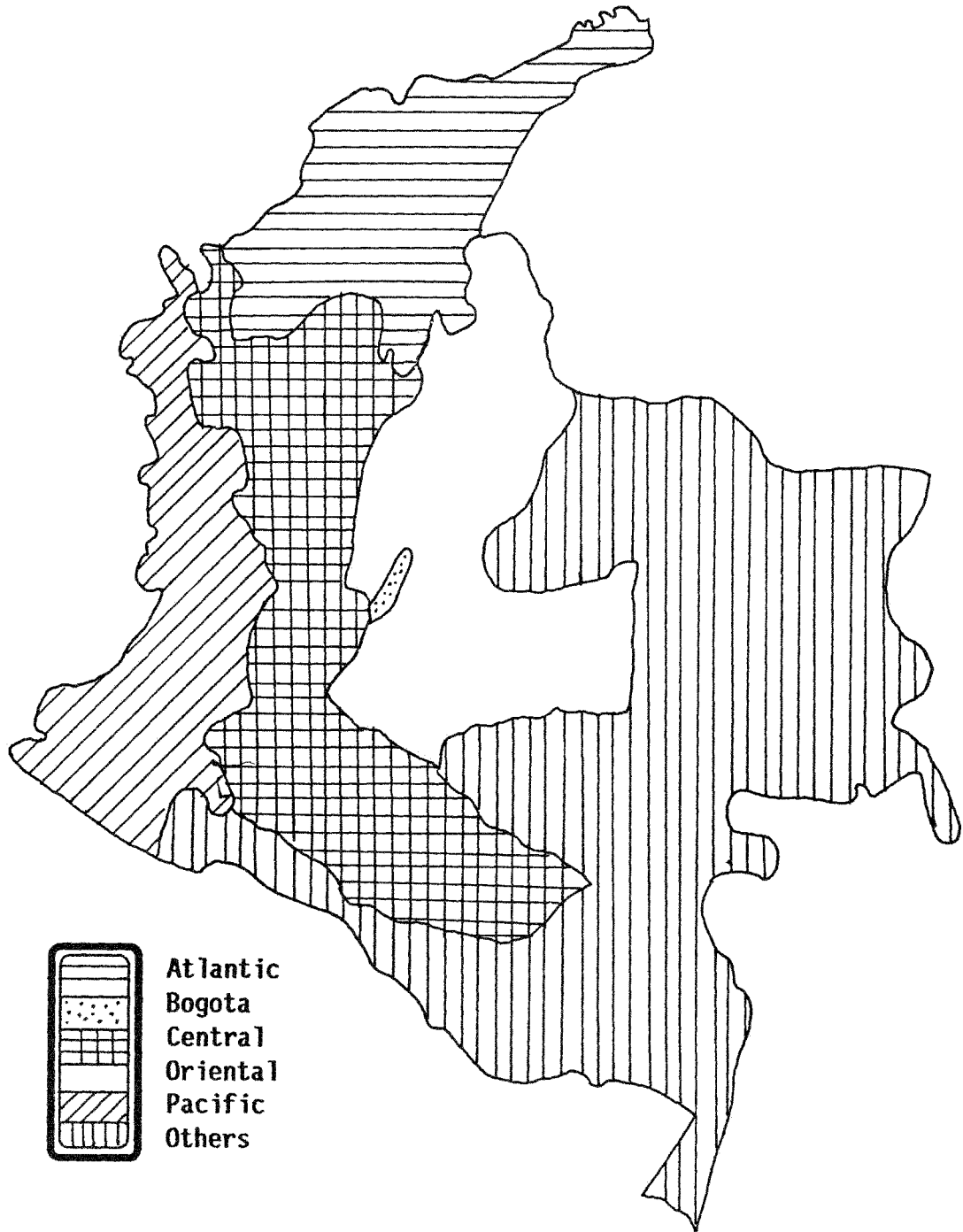
Table 3

Sample Size Stratification

Interval		%	Required Sample			Regions					
p%ile	mm		T	M	F	1	2	3	4	5	6
<5	<1541	5	5	2	3	1	1	1	1	1	0
5<10	1542-1566	5	6	3	3	1	1	1	1	1	1
10<20	1567-1596	10	14	7	7	3	2	3	2	2	2
20<30	1597-1618	10	14	7	7	3	2	3	2	2	2
30<40	1619-1637	10	14	7	7	3	2	3	2	2	2
40<50	1638-1655	10	14	7	7	3	2	3	2	2	2
50<60	1656-1672	10	14	7	7	3	2	3	2	2	2
60<70	1673-1691	10	14	7	7	3	2	3	2	2	2
70<80	1692-1713	10	14	7	7	3	2	3	2	2	2
80<90	1714-1743	10	14	7	7	3	2	3	2	2	2
90<95	1744-1768	5	6	3	3	1	1	1	1	1	1
>95	>1769	5	5	2	3	1	1	1	1	1	0
	TOTAL	100	134	66	68	28	20	28	20	20	18

2.3- POPULATION RECRUITMENT AND RESTRICTIONS.

In order to attain the required sample size, subjects were contacted through the Colombian Consulate and other Colombian associations in South Florida. Subjects, all of all of whom took part on a voluntary basis, were selected randomly and covered all socioeconomic groups. Moreover, to be considered as part of the survey sample, subjects were required to fulfill the following requirements:

1. Geographical location: Colombian people living in South Florida.

2. First generation: Less than 5 years living in U.S.

3. Health: Normal without any serious disease or physical handicap.

4. Sex: Male and female.

5. Ages: 20-64 years.

3- ANTHROPOMETRIC CONCERNS.

3.1- SELECTION AND STANDARDIZATION OF TERMINOLOGY AND TECHNIQUES.

The selection of anthropometric dimensions, anatomical landmarks, anthropometric positions and measurement techniques included in the survey were based on an analysis of each dimensions' relevance for general design purposes, and on international standard lists of anthropometric techniques and terminology (International Standards Organization

[ISO], 1983; Hertzberg, 1968; Taner, 1969; and National Aeronautics and Space

Administration [NASA], 1978).

3.2- ANTHROPOMETRIC DIMENSIONS.

Examination resulted in a list of 20 linear dimensions, standing and sitting, which are

shown in Figures 2 and 3. Definitions are given below in the order in which they were

considered in the analysis of data.

1. Stature: The height of the top of the head.

2. Eye height: The height of the inner corner of the eye.

3. Shoulder height: The height of the acromion.

4. Waist height: The height of the waist level.

5. Dactylion height: The height of the tip of the middle finger measured with the arm,

    hand, and finger extended downward.

6. Elbow height: The height of radiale.

7. Hip breadth: The maximum breadth of the lower torso.

8. Wrist height: The height of the stylion.

9. Upper limb length: The vertical distance from the acromion to the tip of the middle

    finger.

10. Span: The distance between the tips of the right and left middle fingers when the

Figure 2. Selected Standing Anthropometric Dimension.
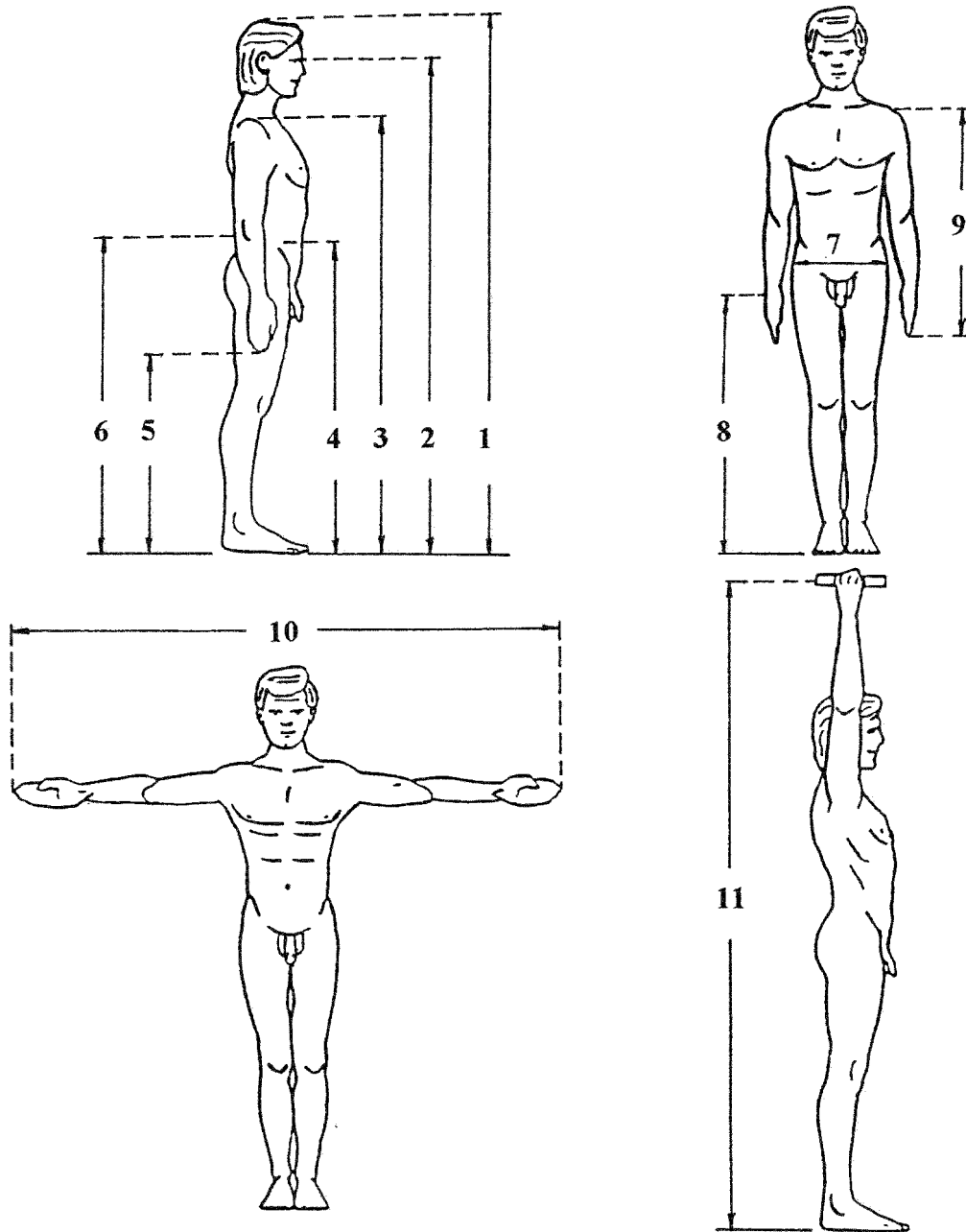
(1) Stature, (2) Eye height, (3) Shoulder height, (4) Waist height, (5) Dactylion height,

(6) Elbow height, (7) Hip breadth, (8) Wrist height, (9) Upper limb length, (10) Span, and

(11) Vertical grip reach.

Figure 3. Selected Sitting Anthropometric Dimensions.
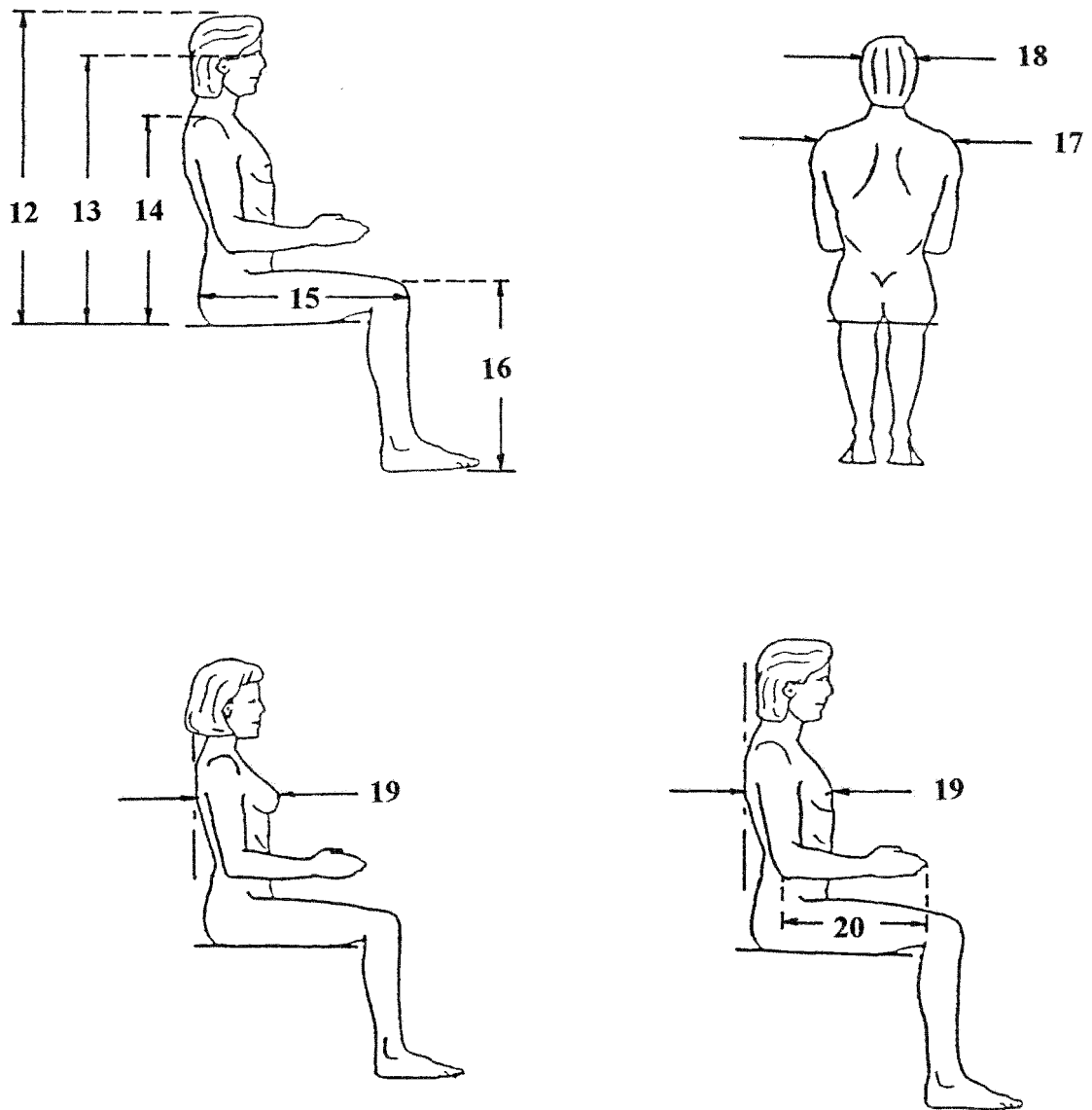
(12) Sitting height, (13) Sitting eye height, (14) Sitting shoulder height, (15) Buttock knee length, (16) Knee height, (17) Shoulder breadth, (18) Head breadth, (19) Chest (bust) depth , and (20) Elbow fingertip length.

subject's arms are extended laterally.

11. Vertical grip reach: The height of a pointer held horizontal in the subject's fist when the arm is maximally extended upward.

12. Sitting height: The height, from the sitting surface, to the top of the head.

13. Sitting eye height: The height of the inner corner of the eye.

14. Sitting shoulder height: The height of acromion above the sitting surface.

15. Buttock knee length: The horizontal distance from the rearmost surface of the buttocks to the front of the kneecaps.

16. Knee height: The height, from the footrest surface to the musculature just above the knee.

17. Shoulder breadth: The distance across the shoulders from right to left acromions.

18. Head breath: The maximum breadth of the head.

19. Chest-bust depth: Chest: The depth of the torso measured at nipple level. Bust: The horizontal distance from the subject's back to the tip of her bra.

20. Elbow fingertip length: The distance from the tip of the elbow to the tip of the longest finger.

3.3- ANATOMICAL LANDMARKS.

Critical anatomical landmarks were located with reference to definite points of the

skeleton to facilitate palpation of the landmarks. Figures 4 and 5 show selected anatomical points.

Anatomical points used in locating body landmarks were grouped according to their position on the body, and their definitions are given below:

1. The head:

- Canthus: The inner corner of the eye.

- Parietal: Convex bones, that form part of the walls of the calvaria.

- Vertex: The most superior part of the skull.

2. The upper limb:

- Acromion: The most prominent posterior lateral bony of the spine of the scapula, point of the shoulder.

- Dactylion: The tip of the distal phalange of the middle finger.

- Olecranon: The most posterior aspect border of the ulna.

- Radial Stylion: The distal end of the radious.

3. The lower limb:

- Buttock or gluteal region: The prominence on each side formed by the gluteal muscles.

- Hip: The region between the iliac crest and the greater trochanter of the femur.

- Patella: Is a triangular sesamoid bone, embedded in the quadriceps femoris tendon.

- Soles or plantar surfaces: The inferior surface of the foot.

Figure 4. Selected Anatomical Points.

Figure 4. Selected Anatomical Points.
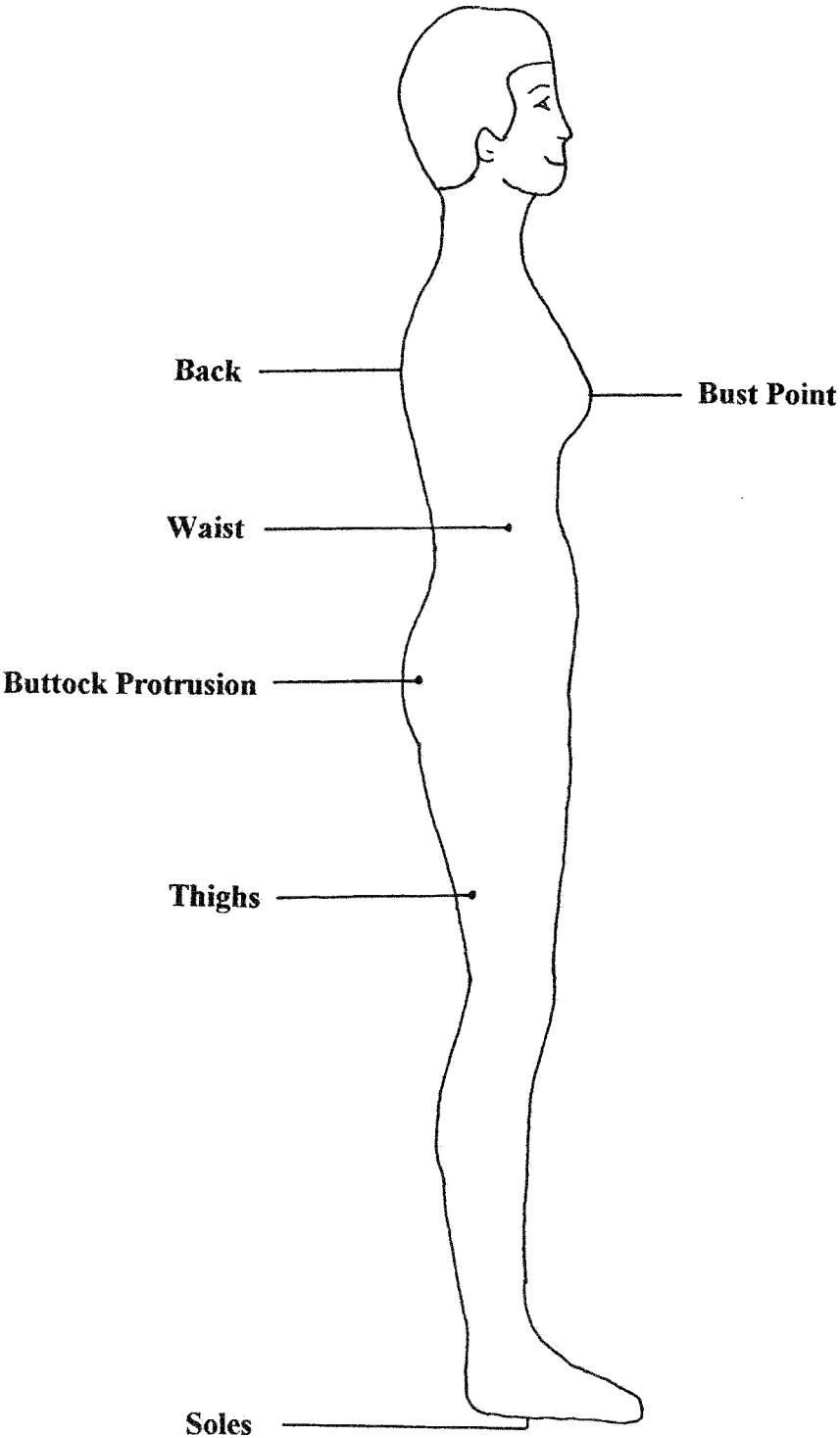
Figure 5. Selected Anatomical Points.
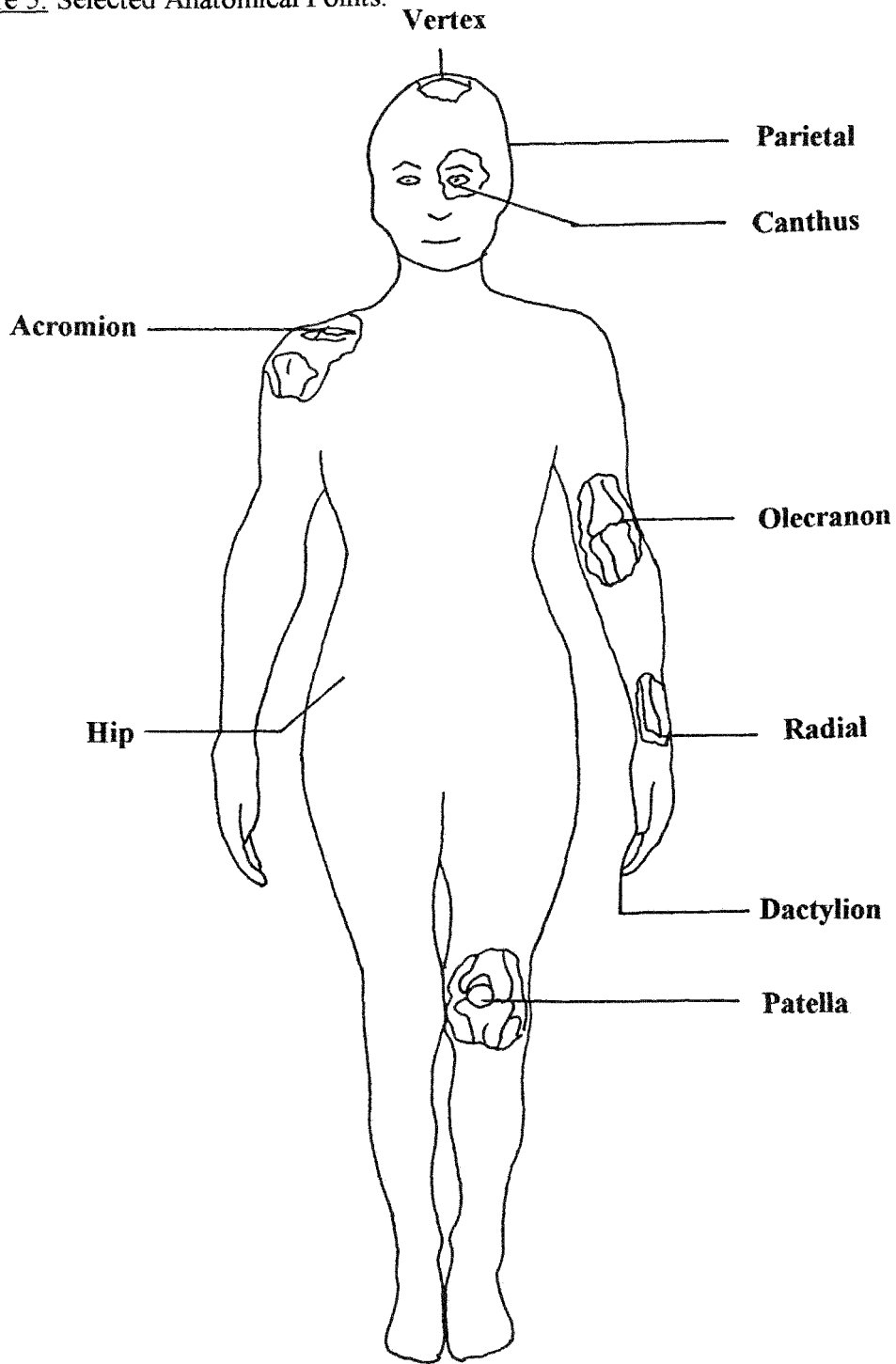
4. The trunk:

- Chest: The anterior surface of the torax, overlying the pectoral muscles.

- Waist: Part of the body between the ribs and the hips.

After palpation of the landmarks, anatomical reference points were placed and marked with small crosses using a skin pencil when possible. Small crosses where used because the intersection of two lines was more satisfactory than a dot as a measuring point of reference.

3.4- ANTHROPOMETRIC POSITION.

To avoid variations in subject positioning, measurements were taken with subjects in one of the two standard positions: standing or sitting erect. In addition, when the subject's position was important and he or she was measured in a position other than one of these two, position was described in the measurement procedure.

For the measurements made on the body standing erect, the subject's body weight is evenly distributed between both feet, heels together as closely as possible, legs and torso straight without stiffness and head erect with the line of vision parallel to the floor. The arms hang straight but loosely at the sides with the palms alongside but not touching the thighs.

To assume the standard posture in sitting erect, the subject sits on a cushionless flat

surface, feet on an adjustable footrest so that the knees are flexed to 90 degrees, the long

axis of the thighs parallel. The trunk is erect without stiffness and the head is also erect

with the path of vision parallel to the plane of the floor. The upper arms are hanging

loosely at the sides with elbows flexed at 90 degrees while forearms and hands are held at

right angles to the body (NASA, 1978). Figures 6 shows selected anthropometric standard

postures.

3.5- MEASUREMENT TECHNIQUE.

Procedures followed in taking each measurement were determined after a wide review

of techniques in the literature including procedures reported by Hertzberg (1968), NASA

(1978), and Lohman, Roche, Martorell (1988).

A manual of measurement procedures, Appendix A, was compiled to be used by the

measurement team as a reference book during the training period and in the measuring

session. The manual is divided into four parts: The first, introduction, describes the survey

and manual aims. The second describes in detail ,for each dimension, the following: (a)

dimension definition, (b) landmarks definitions, (c) position of subject, (d) position of

measurer, (e) procedure to be followed in taking measurement, and (f) remarks. The third

part, is composed of an anatomical and anthropometric terminology glossary, and the

fourth shows an illustrated glossary of the anatomical planes, orientations and landmarks.

Figure 6. Selected Standard Postures.

Standing
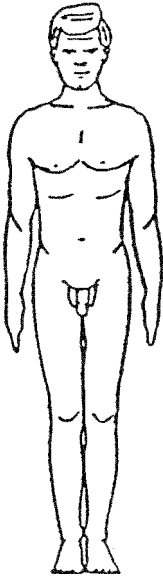
Sitting
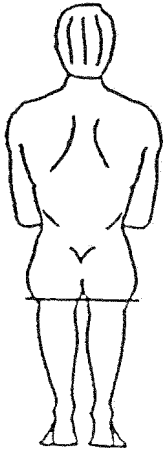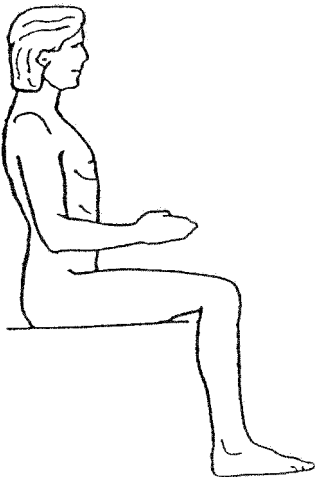
4- MATERIALS.

4.1- EQUIPMENT.

In order to allow a rapid and accurate measurement of the linear dimensions required during the survey, a grid system was designed and manufactured on campus. It consisted of two sheets of plywood hinged together so they stand at right angles; then, pieces of millimeter paper were laminated, to prevent paper wear and tear, and fastened on the walls in such position that they formed a tape measurer on the walls, (see Figure 7). Subjects could be placed in front of the grid, and the projections of the body landmarks to the grid could be used to determine the dimension's values.

Certainly body dimensions could not be projected onto the grid system mentioned above, therefore, several anthropometric instruments, (GPM anthropometer, straight and spreading calipers, and measuring tape), were used to measure these dimensions.

The most important was the anthropometer, which consists of a graduated rod with a sliding branch at a right angle to the rod. This sliding branch allows reaching behind corners and folds of the body whose distances from the reference are read from the scale rod. The rod itself can usually be sectioned for ease of transport and storage. The anthropometer has one branch permanently affixed to its top part. This allows distance measurements between the fixed and the sliding branches: this set up is called a sliding caliper.

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Figure 7. Grid System.
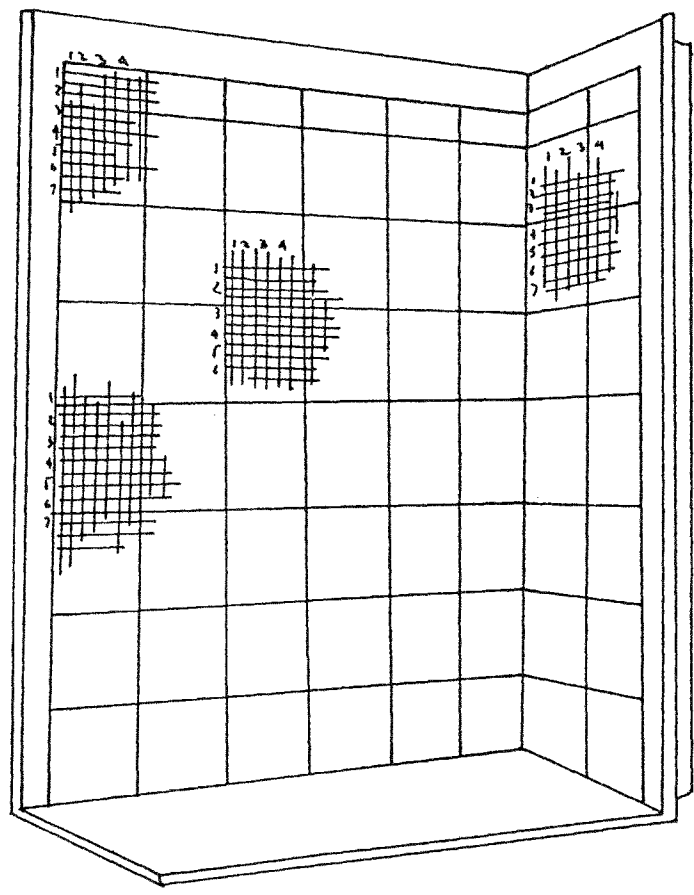
In addition, a spreading caliper was used to take some measurements, it consists of two curved branches which are joined in a hinge, and the distance between the tips of the two opposing ends are read on a scale which is attached in a convenient place between the two parts of the caliper.

An adjustable footrest and a table were employed to obtain the sitting measurements; moreover, skin pencils, measurement manuals and recording forms were utilized in the measurement session.

Instruments used in this study recorded measurements in the metric system, and all physical measurements readings were recorder in millimeters. To maintain accuracy, instruments were periodically calibrated against reliable standard gage blocks. Gage blocks are small blocks of hard dimensionally stable steel or other material, made up in sets which can be stacked up to provide accurate dimensions in the calibration process.

4.2- MEASUREMENT TEAM.

To ensure maximum reliability on the measurement process a work team was selected. It consisted of 2 measurers, the principal investigator of this project and a student of the Industrial Engineering graduate program at Florida International University.

4.3- MEASUREMENT SESSION PLACE.

All measurement session took place in the Ergonomics Laboratory at Florida International University, Miami, Florida. To provide an appropiate workplace environment during the measuring session, anthropometric equipment was positioned in such way that it provided enough room and comfort for subjects and measurers; furthermore, temperature in the laboratory was air conditioned at 22-25 Celsius degrees.

4.4- DATA COLLECTION.

In order to collect the subject data required in the survey, a special recording form was designed. The form was divided into two parts: The first included the following subject information: (a) date of birth, (b) age, (c) sex, (d) name, (e) place of birth, (f) occupation, and (g) date of measurement. The second included a list of dimension to be taken in the survey. The data collection form is included in Appendix C.

5- EXPERIMENTAL PROCEDURE.

5.1- MEASURERS TRAINING.

Before beginning the training period, a manual of measurement procedures (which described in detail the survey aims, the placing of the necessary body landmarks, and the methods to be followed in taking measurements), was supplied to each measurer to be examined and used as a reference book during the training and in the field work.

A training period of one week prior to commencing any field measurements was carried out. Initially the two measurers trained together to ensure, as far as possible, cooperation within the team, familiarity with the care and operation of the equipment, and standardization of landmarks, postures and measuring technique. The training period was also used to test the equipment, different designs of field work layout, and the consistency between trials for a given measurer and between different measurers (accuracy).

5.2- MEASUREMENTS RELIABILITY.

To check on consistency in the measuring process before permanent measurements began, estimates of the reliability of measurers taken by the work team were obtained. Two reliability tests were conducted: Within-observer and between observers.

Observers reliability was measured using the Standard Error of Measurement (SEM) technique, which is based on the differences between the actual readings and the mean. Thorndike (1982) defined SEM for a given body dimension as:

$$SEM = SD * (1 - r)^{1/2}.$$

Where:

SD = Standard deviation of the readings (equal in the two readings).

r = Correlation or reliability coefficient, with

$$r = \{[\,(X - \overline{X}) * (Y - \overline{Y})] / (n - 1)\,] / [\,(\text{variance x})^{1/2} * (\text{variance y})^{1/2}\,].$$

where r is the covariance of each pair of readings x and y averaged across all pair of readings divided by the product of the variance's square root of all pairs of readings x and y. The smaller the statistic (SEM) the greater is the reliability of the observer. The value of the statistic lies in being able to make statements about the limits within which the true value of a given body dimension lies on a certain percentage of occasions. For large samples, the bounds will encompass the true body dimension on 95% of occasions.

$$\pm (1.96) * (\text{SEM})$$

5.2.1- WITHIN AND BETWEEN OBSERVER RELIABILITY TEST.

For these tests, each observer measured 20 subjects, 10 male and 10 female, in 5 different positions using the procedures described in Appendix A. For the first test, within observer reliability, all dimensions were taken twice by each observer, and subjects were completely repositioned for the second set of measurements. For each observer, the SEM was calculated for each body dimension; moreover, because of the variation between

observers in the SEM for a given dimension, an average of the SEM values was calculated. This pooled value gives estimates of within observer variation, and draws attention to dimensions where there is little or considerable variation in measurement. Results are shown in Table 4. Examination of results for all body dimension across observers shows a low degree of variation, with a reliability coefficient (r) ranged from 0.9350 to 0.9970, the SEM varied from 3.29 mm to 5.74 mm, and the SEM averaged from 4.37 mm to 4.74 mm.

For the second test, between observer reliability, body dimensions were measured by both observers. The subject was completely repositioned between measurements by each observer, and the SEM was calculated for each body dimension. Results are shown in Table 4. Results between observers also showed a low degree of variation, with a reliability coefficient (r) ranged from 0.9474 to 0.9964, and the SEM varied from 4.03 mm to 6.93 mm.

In general, reliability results showed that for given body dimensions, the within and between observer reliability were very high, to a first order of approximation in most cases, and that no measurement on any body dimension is absolutely precise.

In order to establish the accuracy bounds for all anthropometric dimensions, it was decided to use the SEM average value of 5 mm, and a confidence limit of 95%. Therefore, the accuracy bounds

Table 4

Measurement Reliability - Within and Between Observer Tests

Within Observer Test

Dimension	Observer A		Observer B		Average	
	r	SEM	r	SEM	r	SEM
Stature	0.997	3.73	0.992	5.742	0.994	4.736
Shoulder height	0.993	4.806	0.994	4.434	0.993	4.62
Hip breadth	0.935	5.457	0.979	3.297	0.957	4.377
Sitting height	0.981	5.326	0.99	3.905	0.985	4.615
Shoulder breadth	0.964	5.244	0.976	3.784	0.97	4.514
Minimum	**0.935**	**3.73**	**0.976**	**3.297**	**0.957**	**4.377**
Maximum	**0.997**	**5.457**	**0.994**	**5.742**	**0.994**	**4.736**

Between Observers Test

Dimension	Observers A and B	
	r	SEM
Stature	0.996	4.037
Shoulder height	0.986	6.931
Hip breadth	0.947	4.845
Sitting height	0.983	4.972
Shoulder breadth	0.969	4.881
Minimum	**0.947**	**4.037**
Maximum	**0.996**	**6.931**

Note. r = Reliability Coefficient, and SEM = Standard Error of Measurement.

$$x \pm (1.96) * (5) \text{ or } x \pm 10 \text{ mm.}$$

will encompass the true body dimension on 95% of occasions.

5.3- MEASURING CONDITIONS.

All measurement sessions were carried out in the period between June and September 1994. To minimize inconvenience to subjects, measurements were taken in as short a period of time as possible. It was found that all measurements could be taken on one subject in 10 minutes by a measuring team. However, an average of 8 subjects was measured each day. The whole time taken for measurements in the field was approximately 20 days. During the measurement session, all subjects were required to be seminude or lightly clothed and bare footed. For this purpose, a fitting room was provided for the subjects.

5.4- MEASUREMENT SESSION.

During a brief interview prior to the measuring session, subjects were informed about the study aims, risks and confidentially. In addition, they were asked to provide a written informed consent and some details about their ages, places of birth, places of family origin

and occupations.

For the measuring session, subjects were required to be bare footed and to be seminude or lightly clothed. Measurers located certain landmarks on the bodies of the subjects, and marked them with a small crosses using a skin pencil when possible.

After all landmarks were marked, subjects were properly positioned in a standard posture, and a set of 20 body dimensions, three measurements for each, were conducted following the procedures described in Appendix A. Furthermore, three subjects that discontinued participation before the measurement session was completed were replaced by others with the same required characteristics.

Finally, subject's anthropometric data were transcribed onto a special form and the average of the three trials for each dimension was calculated and used as final data for anthropometric analysis.

6- RESULTS.

Descriptive statistics were summarized in terms of ranges, means, standard deviations (SD), coefficients of variation (CV), standard errors of the means (SEM), and percentiles. Percentiles values ,1st, 5th, 50th, 95th, and 99th, were included to permit various criterion levels to be chosen. Statistical parameters were computed from the male and female populations by using computerized statistical analysis software, and their results are

summarized in Tables 5 and 6.

In the design process, the range of a dimension within the user population which is of interest is generally between the 5th percentile female value and the 95th percentile male value, this ensure accommodation of at least 95th percent of the population. Therefore, based on the anthropometric data given in Tables 5 and 6, dimensional models were calculated for the 5th percentile female and the 95th percentile male. Figures 8 and 9 showed the dimensional models for the Colombian adult male and female respectively.

Table 5

Anthropometric Estimates for Colombian Male Adults

#	Dimension	Range		Mean	S.D.	C.of V.	S.E.M.	Percentiles				
		Min.	Max.					1st	5th	50th	95th	99th
1	Stature	1488	1813	1654	65.7	4	8.1	1501	1546	1654	1762	1807
2	Eye height	1367	1696	1530	64.6	4.2	7.9	1380	1424	1530	1636	1680
3	Shoulder height	1194	1519	1373	61.5	4.5	7.6	1231	1237	1374	1475	1517
4	Waist height	913	1209	1010	60.6	6	7.5	869	911	1011	1110	1152
5	Dactylion height	511	706	621.1	37.3	6	4.6	534	560	621	682	708
6	Elbow height	893	1152	1037	50	4.8	6.1	921	956	1038	1120	1155
7	Hip breadth	254	362	315.3	28.7	9.1	3.5	248	268	315	362	382
8	Wrist height	691	1007	809.2	45.7	5.6	5.6	703	734	809	884	916
9	Upper limb length	673	813	731.5	31.9	4.4	3.9	657	679	732	784	806
10	Span	1542	1841	1697	71.5	4.2	8.8	1531	1580	1697	1815	1864
11	Vertical grip reach	1569	2245	1974	108.9	5.5	13.4	1720	1795	1974	2152	2228
12	Sitting height	786	964	866.8	46.9	5.4	5.8	758	790	867	944	976
13	Sitting eye height	663	868	748	48	6.4	5.9	636	669	748	827	860
14	Sitting shoulder height	497	667	567.9	36.3	6.4	4.5	483	508	568	627	652
15	Buttock knee length	484	630	553.9	29.7	5.4	3.7	485	505	554	603	623
16	Knee height	406	618	507.2	32.4	6.4	4	432	454	507	560	583
17	Shoulder breadth	347	485	424.8	27.3	6.4	3.4	361	380	425	470	488
18	Head breadth	143	173	156.1	6.2	4	0.8	142	146	156	166	171
19	Chest depth	176	296	245.2	27.4	11.2	3.4	181	200	245	290	309
20	Elbow fingertip length	409	491	449.6	17.1	3.8	2.1	410	422	450	478	489

Note. Adults aged 20 - 64 years. All dimensions in millimeters.

Table 6

Anthropometric Estimates for Colombian Female Adults

#	Dimension	Range		Mean	S.D.	C.of V.	S.E.M.	Percentiles				
		Min.	Max.					1st	5th	50th	95th	99th
1	Stature	1449	1649	1545	52.4	3.4	6.5	1423	1459	1545	1631	1668
2	Eye height	1337	1583	1431	51.4	3.6	6.4	1312	1348	1432	1516	1552
3	Shoulder height	1192	1376	1276	46.5	3.6	5.8	1168	1200	1277	1353	1358
4	Waist height	879	1039	958.7	42.4	4.4	5.3	860	889	959	1028	1058
5	Dactylion height	527	677	593.2	36	6	4.5	509	534	593	652	677
6	Elbow height	896	1063	975.4	39.9	4.1	4.9	882	910	975	1041	1068
7	Hip breadth	268	444	314.9	26.3	8.3	3.3	254	272	315	358	376
8	Wrist height	683	847	764.2	37	4.9	4.6	678	704	764	825	850
9	Upper limb length	603	735	673.9	29	4.3	3.6	606	626	674	722	742
10	Span	1453	1871	1573	78.2	5	9.7	1391	1445	1573	1701	1755
11	Vertical grip reach	1529	1996	1842	82.1	4.5	10.2	1651	1708	1842	1977	2034
12	Sitting height	758	913	827.4	32.3	3.9	4	752	774	827	880	903
13	Sitting eye height	647	798	708.2	29.8	4.2	3.7	639	659	708	757	778
14	Sitting shoulder height	447	660	557	32	5.8	4	482	504	557	610	632
15	Buttock knee length	450	607	529.2	29.9	5.7	3.7	460	480	529	578	599
16	Knee height	431	528	473.4	23	4.9	2.9	420	436	473	511	527
17	Shoulder breadth	338	417	371.2	13.6	3.7	1.7	340	349	371	393	403
18	Head breadth	137	172	151.4	7.1	4.7	0.9	135	140	151	163	168
19	Chest depth	174	570	256.1	48.2	18.8	6	144	177	256	335	368
20	Elbow fingertip length	359	446	407.6	19.1	4.7	2.4	363	376	408	439	452

Note. Adults aged 20 - 64 years. All dimensions in millimeters.

Figure 8. Dimensional Model for 5th Percentile of the Colombian Adult Female.
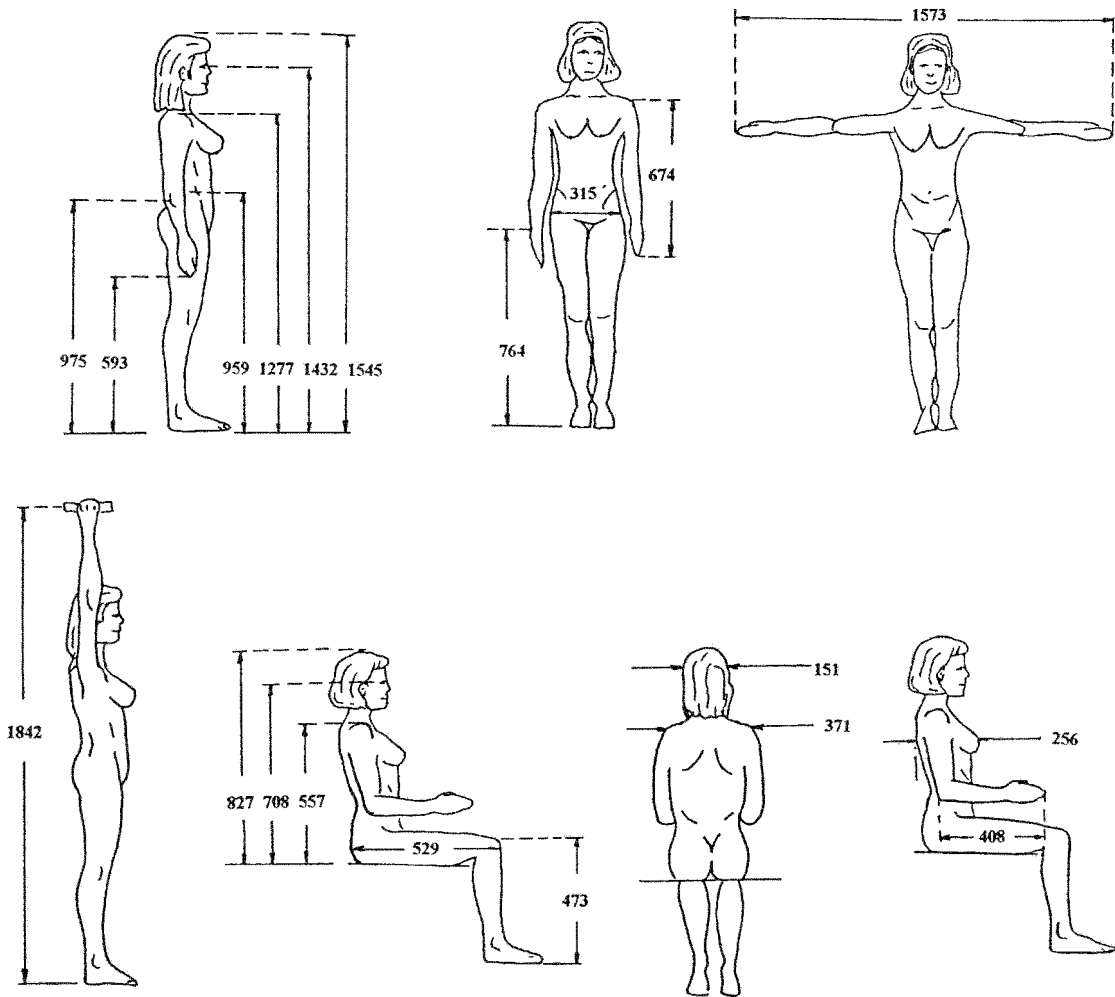
Note. All dimensions in millimeters.

Figure 9. Dimensional Model for 95th Percentile of the Colombian Adult Male. *
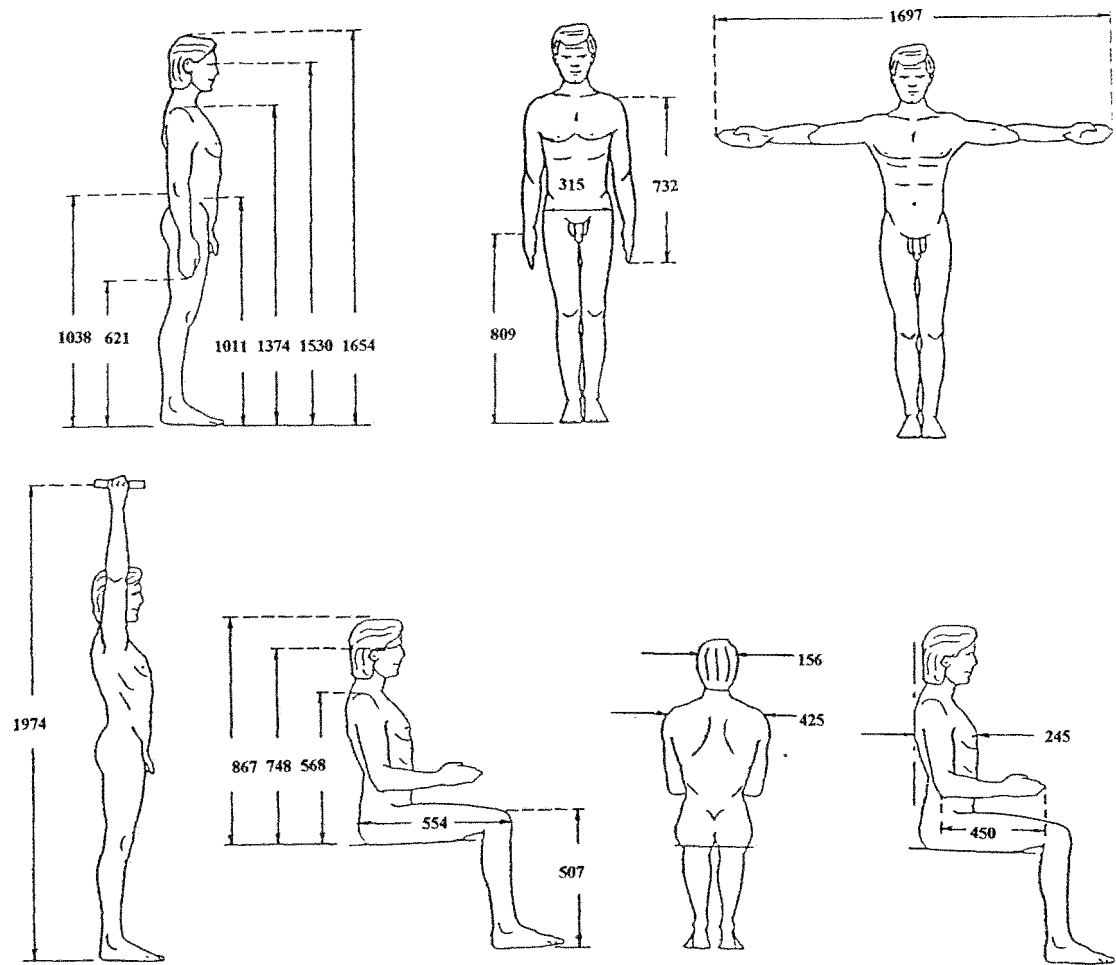
Note. All dimensions in millimeters.

CHAPTER III - ESTIMATION METHOD

1- SCALING RATIO METHOD.

1.1- ANTHROPOMETRIC SOURCES.

Anthropometric data for Latin American populations have not been well documented. There have been some large scale anthropometric surveys, but most of them have been conducted only for the military sector. The most important is a survey conducted by Dobbins and Kindick (1972), on 1850 army personal from various Latin American countries. Eighteen countries were included, 10 from South America, 6 from Central American and one from the Caribbean. The largest population was from Chile: 411, a few more than 200 subjects were from both Colombia and Ecuador; and between 100 and 200 from other countries: Bolivia, Panama, Peru, and Venezuela. For the civilian populations, few surveys have been conducted, and most of them only included male subjects. Therefore, there is a need for civilian, male and female, accurate anthropometric data.

Anthropometric data sources dealing with adult Latin American populations were collected and divided into two groups: A and B. Sources in group A were considered as a "Reference Population", and they were required, as much as possible, to be similar in age, sex, and ethnicity to the Colombian adult population for whom anthropometric estimates were required. Group A included the following male populations: (a) Brazilian (Ferreira,

1988), (b) Latin American Armed Forces (Dobbins and Kindick, 1972), (c) Mexican (Kelly, 1947), and (d) Puerto Rican (Thieme, 1959). For the Latin American female populations few representative anthropometric studies were found; therefore, a selection of international female anthropometric data was compiled to be used as a reference population. Sources selected also were required to be similar in age, sex and to have a mean stature value close to 1650 mm, which was the mean stature value of the Colombian female population reported by MINSALUD (1980). Group A included the following female sources: (a) Chinese (Pheasant, 1988), (b) Indian (Eveleth and Tanner, 1976), (c) Japanese (NASA , 1978), (d) Polish (Batogowska and Slowikowski, 1973), (e) Puerto Rican (Thieme, 1959), and (F) Turkish (Gonen, Kalinkara and Ozgen, 1991).

Group B was considered as a "Target Population" for which estimates of various dimensions were required. It included the results of the Colombian adult anthropometric survey conducted in this study. Only the following stature data was used for predictive purposes: (a) Male: mean of 1654 mm and standard deviation of 65.7 mm, and (b) Female: mean of 1545 mm and standard deviation of 52.4 mm.

1.2- DIMENSIONS SELECTION.

Selection of anthropometric dimensions to be included in the study was based on an analysis of each dimensions relevance for general design proposes, and on the availability

of dimension information in the reference populations. Dimensions selected from comparison between studies, were required to be defined and measured using the same technique; moreover, dimensions which were calculated on estimation techniques rather than direct measurement were excluded.

Examination resulted in a list of 18 linear dimensions, 11 for male and 18 for female, which are shown in Figures 10 and 11 respectively. Definitions are given below in the order in which they were considered in the data analysis.

1. Eye height: The height of the inner corner of the eye.

2. Shoulder height: The height of the acromion.

3. Waist height: The height of the waist level.

4. Dactylion height: The height of the tip of the middle finger measured with the arm, hand, and finger extended downward.

5. Elbow height: The height of the radiale.

6. Hip breadth: The maximum breadth of the lower torso.

7. Upper limb length: The vertical distance from the acromion to the tip of the middle finger.

8. Span: The distance between the tips of the right and left middle fingers when the subject's arms are maximally extended laterally.

9. Vertical grip reach: The height of a pointer held horizontal in the subject's fist when the

Figure 10. Selected Anthropometric Dimensions from Male Reference Populations.
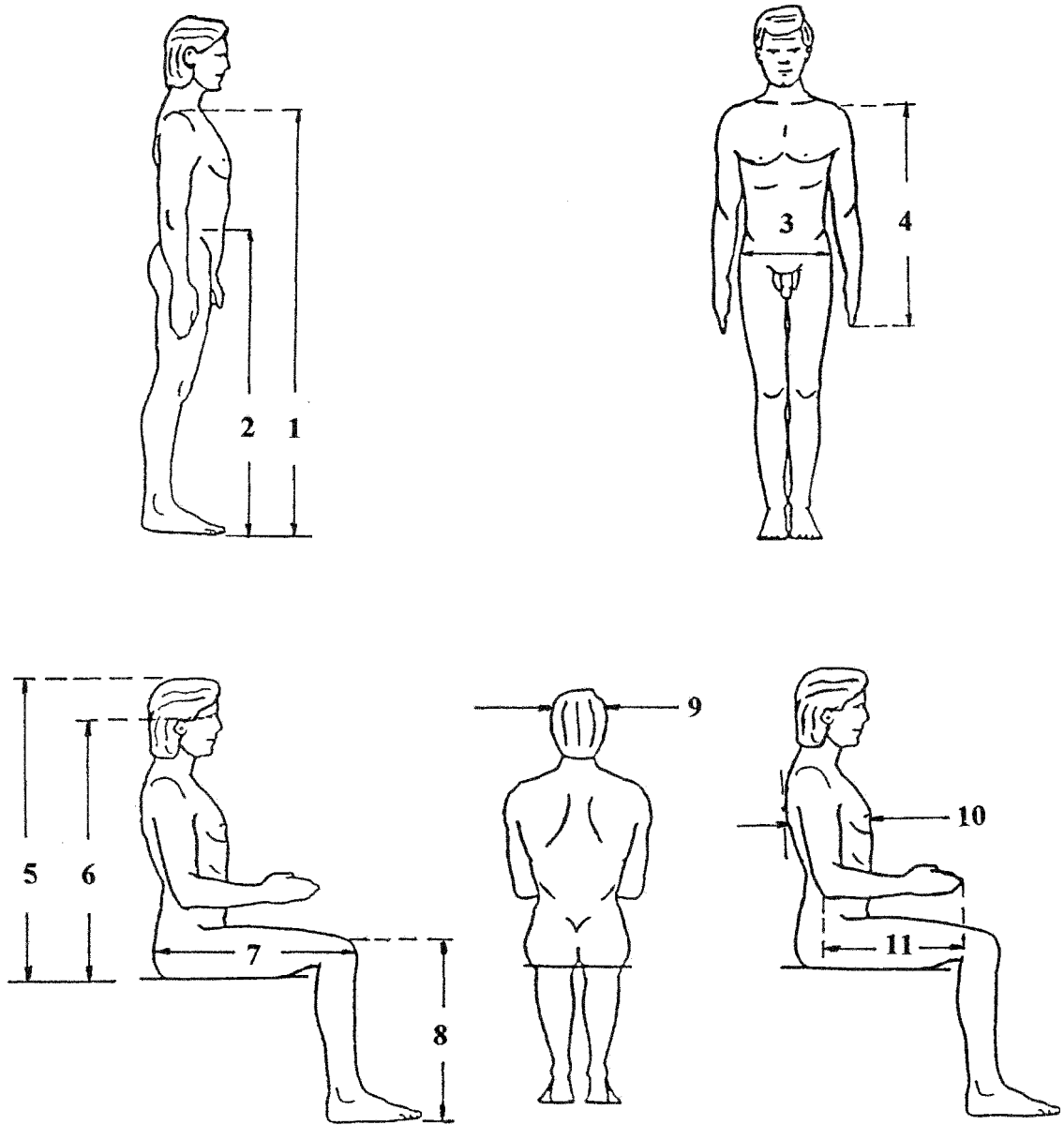
(1) Shoulder height, (2) Waist height, (3) Hip breadth, (4) Upper limb length, (5) Sitting

height, (6) Sitting eye height, (7) Buttock knee length, (8) Knee height, (9) Head breadth,

(10) Chest depth, and (11) Elbow fingertip length.

Figure 11. Selected Anthropometric Dimensions from Female Reference Populations.
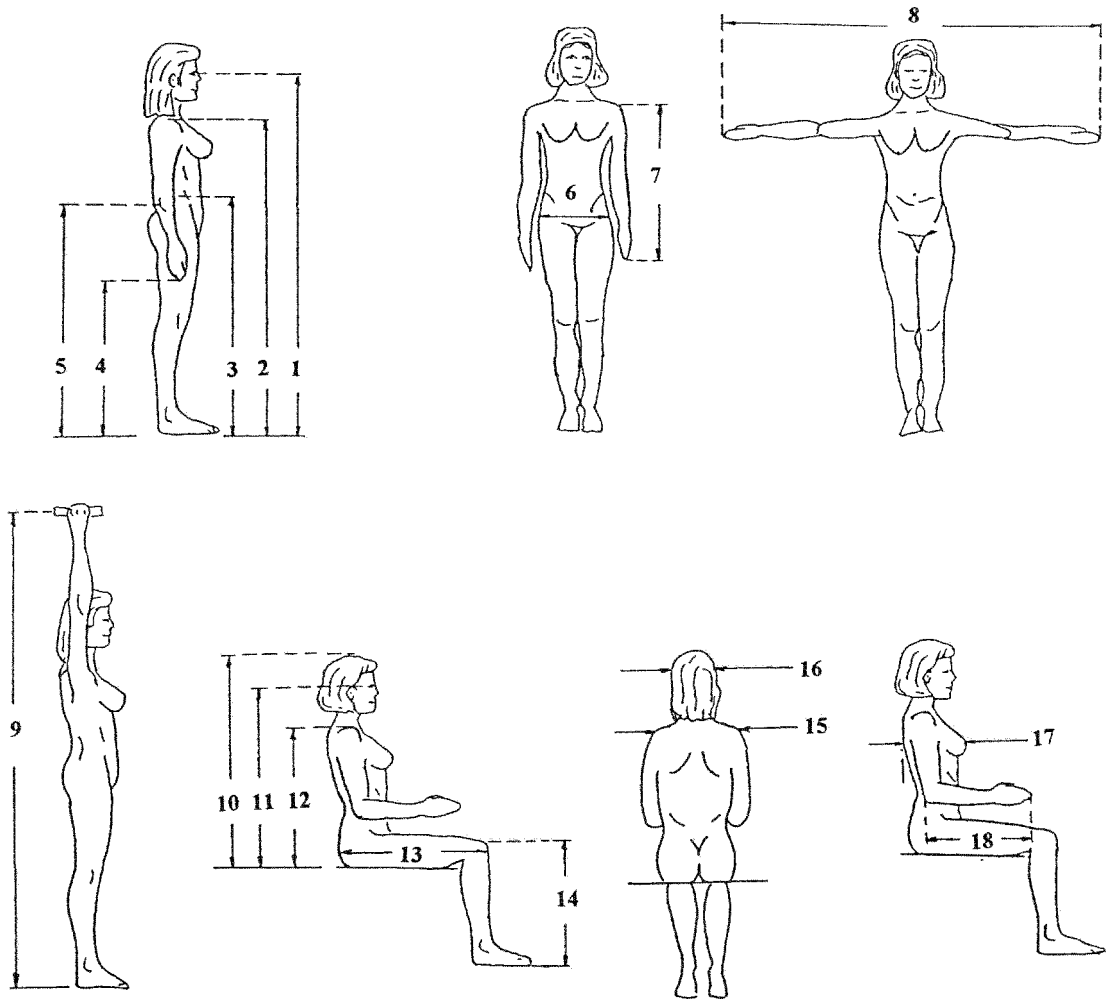
(1) Eye height, (2) Shoulder height, (3) Waist height, (4) Dactylion height, (5) Elbow height, (6) Hip breadth, (7) Upper limb length, (8) Span, (9) Vertical grip reach, (10) Sitting height, (11) Sitting eye height, (12) Sitting shoulder height, (13) Buttock knee length, (14) Knee height, (15) Shoulder breadth, (16) Head breadth, (17) Chest (bust) depth, and (18) Elbow fingertip length.

arm is maximally extended upward.

10. Sitting height: The height, from the sitting surface, to the top of the head.

11. Sitting eye height: The height of the inner corner of the eye.

12. Sitting shoulder height: The height of acromion above the sitting surface.

13. Buttock knee length: The horizontal distance from the rearmost surface of the buttocks to the front of the kneecaps.

14. Knee height: The height, from the footrest surface to the musculature just above the knee.

15. Shoulder breadth: The distance across the shoulders from right to left acromion.

16. Head breath: The maximum breadth of the head.

17. Chest-Bust depth: Male: The depth of the torso measured at nipple level. Female: The horizontal distance from the subject's back to the tip of her bra.

18. Elbow fingertip length: The distance from the tip of the elbow to the tip of the longest finger.

Tables 7 and 8 show the selected dimensions' anthropometric data for the male and female reference populations respectively.

1.3- EXPERIMENTAL PROCEDURE.

1.3.1- COEFFICIENTS AND SCALING FACTORS.

Table 7

Selected Anthropometric Data from Male Reference Populations

		Population							
		Latin Armmy		Puerto Rican		Mexican		Brazilian	
	Dimension	Mean	SD	Mean	SD	Mean	SD	Mean	SD
*	Stature	1670	59	1645	64.3	1659	54.4	1699	67
1	Shoulder height	1376	55						
2	Waist height	1009	48						
3	Hip breadth	321	17						
4	Upper limb length			731	39.1	732	33.8		
5	Sitting height	867	32			870	29.6	881	35
6	Sitting eye height	737	40						
7	Buttock knee length	568	27						
8	Knee height	512	25						
9	Head breadth	152	0.6	150	5.75	150	5.05		
10	Chest depth	228	17			209	12.9		
11	Elbow fingertip length	459	22						

Note. All dimensions in millimeters.

Table 8

Selected Anthropometric Data from Female Reference Populations

		Population											
		Puerto Rican		Indian		Japanese		Chinese		Turkish		Polish	
	Dimension	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
*	Stature	1527	57	1515	61	1530	48	1555	60	1565	54	1575	58
1	Eye height			1420	60	1425	47	1425	57	1449	53	1485	57
2	Shoulder height			1235	57	1145	44	1265	51	1299	50	1280	68
3	Waist height					932	37						
4	Dactylion height			590	38	600	35	610	44	577	42	645	32
5	Elbow height			950	45	955	36	935	41	963	49	985	43
6	Hip breadth			330	35	305	20	330	21			360	26
7	Upper limb length	664	37	665	32	645	25	660	26			700	28
8	Span			1515	69	1485	56	1480	80			1610	65
9	Vertical grip reach			1794	69	1795	69	1825	86	1978	82	2005	79
10	Sitting height			790	35	845	28	840	37			825	33
11	Sitting eye height			690	33	735	28	720	35			725	35
12	Sitting shoulder height			515	31	555	26	560	29			565	31
13	Buttock knee length			540	29	530	26	520	30	547	30	565	29
14	Knee height			470	26	450	18	455	27	478	34	485	24
15	Shoulder breadth			315	17	340	15	350	22			350	17
16	Head breadth	144	5	135	5	150	6	150	8			150	5
17	Chest depth(bust)			210	26	205	18	215	34			245	25
18	Elbow fingertip length			405	19	400	17	400	24			420	18

Note. All dimensions in millimeters.

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For each population and dimension in group A (reference population), two

coefficients, e1 and e2 were obtained:

$$e1 = Md / Ms.$$

$$e2 = Sd / Ss.$$

where Md is the mean value of the dimension in the population; Ms is the mean stature in

the population; Sd is the standard deviation of the dimension in the population; and Ss is

the standard deviation of the stature in the population.

For each dimension, taking male and female data separately, arithmetic means E1 and

E2 of values e1 and e2 of the reference populations were calculated:

$$E1 = \sum_{i=1}^{n} (e1) / n.$$

$$E2 = \sum_{i=1}^{n} (e2) / n.$$

where n varied depending on the dimension considered, since not all dimensions were

available in all the populations.

Scaling factors (E1 and E2) derived from the group A (reference population) were

used to predict the statistical parameters of other body dimension in group B (target

population). For each dimension, the 1st, 5th, 50th, 75th, 95th and 99th percentile values

were calculated using the following expression:

$$ph \text{ \%ile} = (E1 * MsB) - (Z * E2 * SsB) .$$

where E1 and E2 are the related dimension's scaling factor, MsB is the mean stature of the

group B (target population), SsB is the standard deviation stature of group B (target

population), and Z is a constant for the percentile concerned in a normal distribution.

2- RESULTS.

Tables 9 and 10 summarized the minimum and maximum e values as well as the

average scaling factors (E1 and E2) values for male and female subjects respectively.

For purposes of method validation, anthropometric estimates for the 1st, 5th, 50th,

95th and 99th percentiles were also calculated based on the scaling ratios given in Tables

9 and 10, and on the stature's statistics results of the survey conducted as a reference in

this study (Chapter II). Estimates for the male and female subjects are shown and

compared with the true results of the reference survey in Tables 11 and 12 respectively.

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Table 9

Scaling Factors of the Distribution of Stature for Males

		Scaling Factors					
		e1	E1	e1	e2	E2	E2
	Dimension	Min.	Mean	Max.	Min.	Mean	Max.
1	Shoulder height		0.824			0.932	
2	Waist height		0.604			0.814	
3	Hip breadth		0.192			0.288	
4	Upper limb length	0.441	0.443	0.444	0.608	0.615	0.621
5	Sitting height	0.518	0.521	0.524	0.525	0.536	0.544
6	Sitting eye height		0.441			0.678	
7	Buttock knee length		0.340			0.458	
8	Knee height		0.307			0.424	
9	Head breadth	0.090	0.091	0.092	0.010	0.064	0.092
10	Chest depth	0.126	0.131	0.136	0.238	0.263	0.288
11	Elbow fingertip length		0.275			0.373	

Table 10

Scaling Factors of the Distribution of Stature for Females

	Dimension	Scaling Factors					
		e1 Min.	E1 Mean	e1 Max.	e2 Min.	E2 Mean	e2 Max.
1	Eye height.	0.916	0.931	0.943	0.937	0.975	0.983
2	Shoulder height.	0.748	0.804	0.83	0.85	0.96	1.172
3	Waist height.		0.609			0.771	
4	Dactylion height.	0.369	0.39	0.41	0.552	0.684	0.785
5	Elbow height.	0.601	0.619	0.627	0.683	0.764	0.907
6	Hip breadth.	0.199	0.214	0.229	0.35	0.447	0.574
7	Upper limb length.	0.422	0.433	0.444	0.443	0.521	0.664
8	Span.	0.952	0.986	1.022	1.121	1.188	1.333
9	Vertical grip reach.	1.173	1.214	1.273	1.131	1.375	1.511
10	Sitting height.	0.521	0.534	0.552	0.569	0.585	0.617
11	Sitting eye height.	0.455	0.465	0.48	0.541	0.578	0.603
12	Sitting shoulder h.	0.34	0.355	0.363	0.483	0.517	0.542
13	Buttock knee length.	0.334	0.349	0.359	0.475	0.513	0.548
14	Knee height.	0.293	0.302	0.31	0.375	0.46	0.637
15	Shoulder breadth.	0.208	0.219	0.225	0.279	0.313	0.367
16	Head breadth.	0.089	0.095	0.098	0.082	0.104	0.133
17	Chest depth (bust).	0.134	0.142	0.156	0.375	0.45	0.567
18	Elbow fingertip l.	0.257	0.263	0.308	0.31	0.344	0.431

Table 11

Comparison of Anthropometric Male Estimates Between Scaling Ratio and Survey

Results

		Method									
		Scaling Ratio					Anthropometric Survey				
		Percentiles					Percentiles				
	Dimension	1st	5th	50th	95th	99th	1st	5th	50th	95th	99th
1	Shoulder height	1220	1262	1363	1463	1506	1231	1237	1374	1475	1517
2	Waist height	874	911	999	1087	1124	869	911	1011	1110	1152
3	Hip breadth	273	287	318	349	362	248	268	315	362	382
4	Upper limb length	639	666	733	799	827	657	679	732	784	806
5	Sitting height	780	804	862	919	944	758	790	867	944	976
6	Sitting eye height	626	656	729	802	833	636	669	748	827	860
7	Buttock knee length	492	513	562	612	632	485	505	554	603	623
8	Knee height	443	462	508	553	573	432	454	507	560	583
9	Head breadth	141	144	151	157	160	142	146	156	166	171
10	Chest depth	176	188	217	245	257	181	200	245	290	309
11	Elbow fingertip length	398	415	455	495	512	410	422	450	478	489

Note. All dimensions in millimeters.

Table 12

Comparison of Anthropometric Female Estimates Between Scaling Ratio and Survey Results

		Method									
		Scaling Ratio					Anthropometric Survey				
		Percentiles					Percentiles				
	Dimension	1st	5th	50th	95th	99th	1st	5th	50th	95th	99th
1	Eye height	1319	1355	1438	1522	1557	1312	1348	1432	1516	1552
2	Shoulder height	1125	1160	1242	1325	1359	1168	1200	1277	1353	1358
3	Waist height	847	875	941	1007	1035	860	889	959	1028	1058
4	Dactylion height	519	544	603	661	686	509	534	593	652	677
5	Elbow height	863	891	956	1022	1050	882	910	975	1041	1068
6	Hip breadth	276	292	331	369	385	254	272	315	358	376
7	Upper limb length	605	624	669	714	733	606	626	674	722	742
8	Span	1378	1421	1523	1625	1668	1391	1445	1573	1701	1755
9	Vertical grip reach	1708	1757	1876	1994	2044	1651	1708	1842	1977	2034
10	Sitting height	754	775	825	875	896	752	774	827	880	903
11	Sitting eye height	648	669	718	768	789	639	659	708	757	778
12	Sitting shoulder height	485	504	548	593	612	482	504	557	610	632
13	Buttock knee length	477	495	539	583	602	460	480	529	578	599
14	Knee height	410	427	467	506	523	420	436	473	511	527
15	Shoulder breadth	300	311	338	365	377	340	349	371	393	403
16	Head breadth	134	138	147	156	159	135	140	151	163	168
17	Chest depth(Bust)	164	181	219	258	274	144	177	256	335	368
18	Elbow fingertip length	364	377	406	436	448	363	376	408	439	452

Note. All dimensions in millimeters.

CHAPTER IV - GENERAL DISCUSSION AND CONCLUSIONS

1- DISCUSSION.

1.1- ANTROPOMETRIC SURVEY.

1.1.1- COMPARISON WITH PREVIOUS INVESTIGATIONS.

There has never been an anthropometric survey of the Colombian population, so it is difficult to compare the current survey findings with those of the general Colombian population. The most recent study of Colombian adults, conducted by MINSALUD et al. in 1980, found very similar stature values. The mean male stature of 1654 mm in the present survey is only 1 mm smaller, while the female stature of 1545 mm is 7 mm taller. However, comparing survey results with those estimates from the scaling ratio analysis (see Chapter III), all body measurements were close, except chest depth in the male population and shoulder height, span and bust depth in the female population. (see Tables 11 and 12 respectively).

1.1.2- COMPARISON WITH OTHER POPULATIONS.

A- LATIN AMERICAN POPULATIONS.

In this study, Colombian anthropometric data were compared with other surveys to identify the unique anthropometric characteristics of the Colombian population. Table 13

shows a comparison of anthropometric data between the Colombian male adult population and other similar ethnic male populations. Body differences amongst Latin American populations were minimal. In general the Colombian male adults are taller than the Puerto Ricans, but smaller than the Brazilian and Mexican adults.

B- EUROPEAN AND JAPANESE POPULATIONS.

Comparisons were also made with some European populations. Results, Table 14, show that there are significant differences in the body build. In general Colombian adults (male and female) are smaller than the British, French and German adults, taller than the Indian adults, and very similar to the Japanese.

C- U.S. POPULATION.

Compared with the American population, Colombian adult males and females are smaller in all body measurements except head breadth and chest (bust) depth. The difference in the mean stature for females is as large as 80 mm, and the difference of 101 mm for males is of great practical significance. Moreover, differences were more pronounced in the male population than the female population, (see Table 15). Moreover, stature and sitting height mean values were compared to examine the differences among those countries exporting man machine systems to Colombia, (U.S., Germany and Japan).

Table 13

<u>Anthropometric Comparison Between Colombian Adult Male Population and Other</u>

<u>Similar Ethnic Male Populations</u>

	Dimension		
Population	Stature	Head Breadth	Sitting Height
Colombian	**1654**	**156**	**867**
Puerto Rican (1)	1645	150	----
Mexican (2)	1659	150	870
Brazilian (3)	1699	----	881
Latin A. Army (4)	1670	152	867

<u>Note.</u> All dimensions in millimeters.

<u>Sources.</u> (1) Thieme, 1959; (2) Kelly, 1947; (3) Ferreira, 1988; and (4) Dobbins & Kindick, 1972.

Table 14

Anthropometric Comparison Between Colombian Adults (Male and Female), Europeans

and Japanese Populations

Population	Stature		Sitting Height		Upper Limb Length	
	M	F	M	F	M	F
Colombian	**1645**	**1545**	**867**	**827**	**732**	**674**
British (1)	1745	1615	915	855	785	710
French (1)	1715	1600	910	860	770	705
German (1)	1745	1635	800	740	785	720
Japanese (1)	1655	1530	900	845	715	645

Note. M and F are abbreviations for male and female respectively. All dimensions in

millimeters. Source. (1) Pheasant, 1988.

Table 15

Anthropometric Comparison Between Colombian Adults (Male and Female), and the

American Population

	Population				
	Colombian			American (1)	
Dimension	M	F		M	F
Stature	1654	1545		1755	1625
Eye height	1530	1432		1710	1525
Shoulder height	1374	1277		1440	1325
Elbow height	1038	975		1105	1020
Upper limb length	732	674		790	715
Sitting height	867	827		915	860
Sitting eye height	748	708		800	750
Buttok knee length	554	529		600	575
Head breadth	156	151		155	145
Chest depth (bust)	245	256		255	255

Note. M and F are abbreviations for male and female respectively. All dimensions in millimeters. Source. (1) Pheasant, 1988.

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1.2- SCALING RATIO METHOD.

1.2.1- METHOD RELIABILITY.

The accuracy of anthropometric estimates using the scaling ratio method depends on the availability of appropiate data sources for the reference and target populations. Sources chosen for this study, to the best of the author's knowledge, were those with the greatest similarity to the Colombian adult population in terms of age, sex and ethnicity; and those most representative of the Latin American population.

In order to evaluate the scaling ratio method reliability, scaling factors derived from reference populations were used to predict the true results of the survey conducted as a reference (Chapter II). For these predictions only the sex, stature mean and standard deviation of the reference survey were used. Moreover, comparisons were made between the predicted percentile values of each dimension, and the real percentile values from the reference survey (see Tables 11 and 12). Differences then were calculated, in millimeters and as percentages of the real values, using the following formulas:

$$d = \text{predicted} - \text{real} .$$

$$d\% = [(\text{predicted} - \text{real}) * 100] / \text{real}.$$

Tables 16 and 17 list the errors in predicting the 1st, 5th, 50th, 95th and 99th

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percentiles for the male and female respectively. For both populations, errors were approximately normally distributed (see Figures 12 and 13). For male population, errors were distributed with a mean of -5 mm and a standard deviation of 17 mm. Of the 55 comparisons, 93% of the errors fell within the range of 0 ± 30 mm. For the female population, errors were distributed with a mean of -7 mm and a standard deviation of 25 mm. Of the 90 comparisons, 83% of the errors fell within the range of 0 ± 30 mm.

The 50th percentile was chosen as a reference value in the validation process. For each dimension, absolute error values of the 50th percentile were arranged in order of overall error for male and female subjects (see Table 18). There was not any direct relation between the error amount and the dimension concerned. Roebuck et al. (1975) has also reported that larger errors are not associated with larger dimensions; nor are they associated with those dimensions known to be poorly correlated with stature.

Using a 95th percent confidence limit, calculation of the margins of error were made for the 50th percentile values of the dimensions in the target population (Colombian anthropometric survey). Calculations were carried out using the following formula:

$$SEM * 1.96.$$

where SEM is the dimension's standard error of the mean, and 1.96 is a statistical value

Table 16

Errors in Prediction of Anthropometric Male Percentile Values Using the Scaling Ratio

Method.

		Percentiles								
		1st		5th		50th		95th		99th	
	Dimension	mm	%	mm	%	mm	%	mm	%	mm	%
1	Shoulder height	-11	-0.89	25	2.02	-11	-0.8	-12	-0.81	-11	-0.73
2	Waist height	5	0.58	0	0	-12	-1.19	-23	-2.07	-28	-2.43
3	Hip breadth	25	10.08	19	7.09	3	0.95	-13	-3.59	-20	-5.24
4	Upper limb lenght	-18	-2.74	-13	-1.91	1	0.14	15	1.91	21	2.61
5	Sitting height	22	2.9	14	1.77	-5	-0.58	-25	-2.65	-32	-3.28
6	Sitting eye height	-10	-1.57	-13	-1.94	-19	-2.54	-25	-3.02	-27	-3.14
7	Buttock knee length	7	1.44	8	1.58	8	1.44	9	1.49	9	1.44
8	Knee height	11	2.55	8	1.76	1	-0.2	-7	1.25	-10	-1.72
9	Head breadth	-1	-0.7	-2	-1.37	-5	-3.21	-9	-5.42	-11	-6.43
10	Chest depth	-5	-2.76	-12	-6	-28	-11.43	-45	-15.52	-52	-16.83
11	Elbow fingertip length	-12	-2.93	-7	-1.66	5	1.11	17	3.56	23	4.7

Table 17

Errors in Prediction of Anthropometric Female Percentile Values Using the Scaling Ratio

Method.

| | | Percentiles | | | | | | | | | |
| | | 1st | | 5th | | 50th | | 95th | | 99th | |
	Dimension	mm	%	mm	%	mm	%	mm	%	mm	%
1	Eye height	7	0.56	7	0.49	6	0.45	6	0.41	5	0.35
2	Shoulder height	-43	-3.68	-40	-3.36	-35	-2.73	-28	-2.09	1	0.1
3	Waist height	-13	-1.54	-14	-1.61	-18	-1.89	-21	-2.03	-23	-2.17
4	Dactylion height	10	1.97	10	1.83	10	1.61	9	1.43	9	1.34
5	Elbow height	-19	-2.15	-19	-2.12	-19	-1.91	-19	-1.82	-18	-1.72
6	Hip breadth	22	8.68	20	7.43	16	4.96	11	3.08	9	2.45
7	Upper limb length	-1	-0.1	-2	-0.29	-5	-0.74	-8	-1.14	-9	-1.27
8	Span	-13	-0.91	-24	-1.64	-50	-3.16	-76	-4.44	-87	-4.93
9	Vertical grip reach	57	3.44	49	2.9	34	1.83	17	0.85	10	0.47
10	Sitting height	2	0.21	1	0.1	-2	-0.24	-5	-0.53	-7	-0.72
11	Sitting eye height	9	1.39	10	1.48	10	1.47	11	1.47	11	1.41
12	Sitting shoulder height	3	0.7	0	0	-9	-1.53	-17	-2.8	-20	-3.23
13	Buttock knee length	17	3.6	15	3.15	10	1.93	5	0.92	3	0.47
14	Knee height	-10	-2.28	-9	-2.05	-6	-1.36	-5	-0.95	-4	-0.81
15	Shoulder breadth	-40	-11.7	-38	-10.7	-33	-8.8	-28	-7.06	-26	-6.56
16	Head breadth	-1	-0.68	-2	-1.54	-4	-2.80	-7	-4.47	-9	-5.08
17	Chest depth(Bust)	20	14.20	4	2.10	-37	-14.30	-77	-22.90	-94	-25.45
18	Elbow fingertip length	1	0.37	1	0.21	-2	-0.41	-3	-0.71	-4	-0.81

Figure 12. Males Error Distribution.
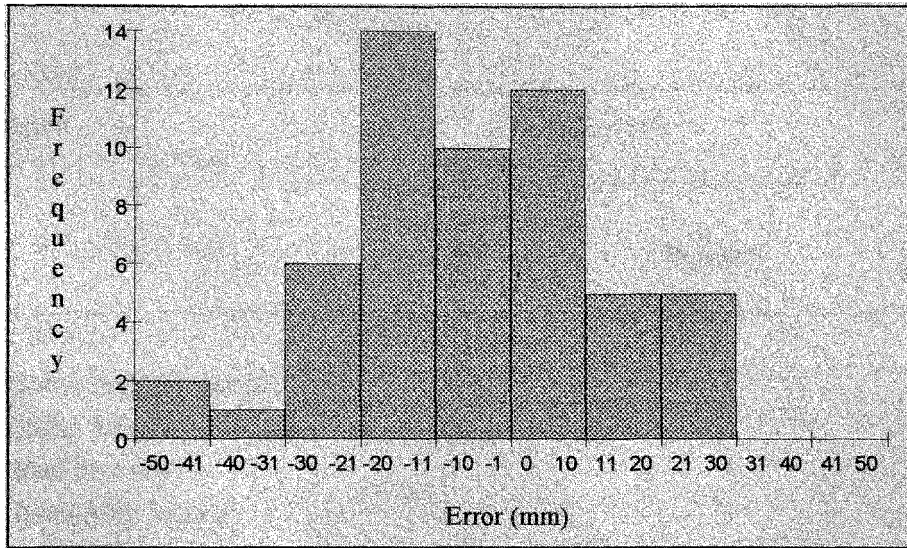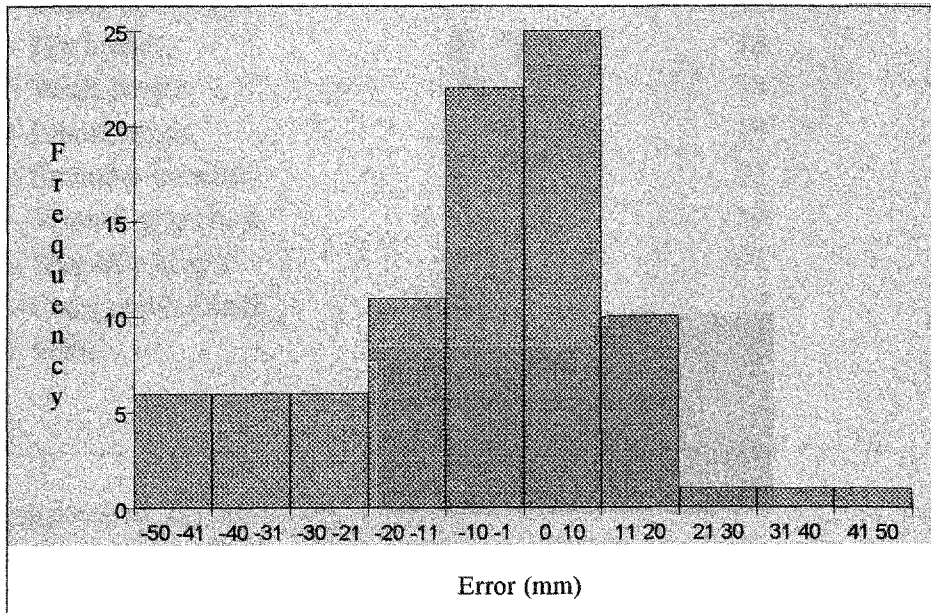

Figure 13. Females Error Distribution.

Table 18

Absolute Error Values

Dimension	Absolute Error	
	Males	Females
1- Elbow fingertip length	5	2
2- Sitting height	5	2
3- Head breadth	5	4
4- Upper limb length	1	5
5- Eye height	-	6
6- Knee height	1	6
7- Sitting shoulder height	-	9
8- Dactylion height	-	10
9- Buttock knee length	8	10
10- Sitting eye height	19	10
11- Hip breadth	3	16
12- Waist height	12	18
13- Elbow height	-	19
14- Shoulder breadth	-	33
15- Vertical grip reach	-	34
16- Shoulder height	11	35
17- Chest depth (bust)	28	37
18- Span	-	50

Note. Absolute errors in millimeters.

concerned with the 95th confidence limit. Confidence limits values were then compared with the errors made in predicting the dimensions concerned. For the male population comparison showed that 8 of the 11 estimates fell within these confidence limits, and errors are modest in comparison with those which may occur in correcting for clothing, shoes etc. But, for the female population only 5 of the 18 estimates fell within these confidence limits, see Table 19.

These considerations suggest that errors associated with the use of estimated data are small when using reference populations similar in age, sex and ethnicity to the population for whom anthropometric estimates are required, but larger when using reference populations of different ethnicities of the target population. It is concluded therefore that in this study the anthropometric data estimated using the scaling ratio method can be considered as a valid representation of the anthropometrics of the general adult Colombian population.

2- CONCLUSIONS.

2.1- SCALING RATIO METHOD.

Since anthropometric surveys are both costly and time consuming, designers are frequently forced to estimate the data they require. Sometimes, there are populations for whom stature parameters are known, but for whom other anthropometric data are

Table 19

Margin of Error for the 50th Percentile Values of the Survey's Dimensions

Dimension	Males		Females	
	ME	Error	ME	Error
1- Elbow fingertip length	4	5	5	2
2- Sitting height	11	5	8	2
3- Head breadth	2	5	2	4
4- Upper limb length	7	1	7	5
5- Eye height	-	-	13	6
6- Knee height	8	1	6	6
7- Sitting shoulder height	-	-	8	9
8- Dactylion height	-	-	9	10
9- Buttock knee length	7	8	7	10
10- Sitting eye height	12	19	7	10
11- Hip breadth	7	3	6	16
12- Waist height	15	12	10	18
13- Elbow height	-	-	10	19
14- Shoulder breadth	-	-	3	33
15- Vertical grip reach	-	-	20	34
16- Shoulder height	15	11	11	35
17- Chest depth (bust)	7	28	11	37
18- Span	-	-	19	50

Note. ME= Margin of Error; all dimensions in millimeters.

insufficient. In other cases, when resources are limited for a detailed investigation, a survey of stature may be possible. In either circumstance, if appropriate reference populations are available, the scaling ratio method can be used for estimation purposes, and will provide data sufficiently accurate for some design applications.

The scaling ratio method used in this study, for estimation of anthropometric data, proved to be satisfactory for accurate and rapid data collection. The set of data obtained may be considered as a valid representation of the anthropometry of the male adult Colombian population, and it will provide a basis for design purposes to be currently applied to the actual user population not only in Colombia, but also in other countries where these data are required.

The use of anthropometric data in the design process will depend on the designers criteria, which define the accuracy and limits within which a satisfactory match between user and equipment will be considered achieved; therefore, when designing with estimated data, instead of real data, discretion always must be employed.

2.2- ANTHROPOMETRY SURVEY.

In general, the Colombian adult (male and female) is smaller than the American, British, French, German, and Brazilian adult; and similar to the Japanese, Mexican, and Puerto Rican adult. Anthropometry of Colombian male adults when compared with those

of American males show that machinery designed for the stature of 90% of American males would accommodate approximately only 58% of the Colombian male population. Table 20 shows the percentage of Colombian adult population (male and female) that will be accommodated in systems imported from other industrialized countries.

Special care should be taken with standing work surfaces, overhead reaches, and seating level in systems and workstations manufactured in U.S. and European countries and intended to be used by the Colombian population. Obviously, considering these anthropometric differences when buying and using imported equipment will prevent many users design related problems.

Earlier, there was a lack of awareness about anthropometric aspects in the design and operation of equipment. However, designers are now developing a consciousness about ergonomics, and if the appropiate anthropometric data are available, they may wish to use them in the design process. It is therefore intended that the anthropometric survey tables, measurement reference manual, and dimensional models published here will constitute a Colombian anthropometric data base which may be used for general design purposes.

Moreover, anthropometric data base can be utilized by designers to provide appropiate design dimensional specifications for equipment, furniture and industrial workplace layouts manufactures, local and abroad, helping in this way to the development of the Colombian industry, and so of benefit to the Colombian workers. Anthropometric tables

Table 20

Percentage of Accommodation for Colombian Population in Imported Equipment

	Dimension			
	Stature		Sitting Height	
Country	Male	Female	Male	Female
	%	%	%	%
Germany	55	68	52	80
Japan	92	96	64	80
U.S.	58	68	60	80

Note. Equipment designed to accommodate 90th % of the native population.

can be also utilized for other populations in Latin America with similar somatic characteristics.

3- FURTHER STUDIES.

Anthropometric tables generated in this study should be applied in workplace layout designs and tested in real industrial settings to evaluate their benefits in terms of improved worker productivity, satisfaction, comfort, and safety. Study findings have also given a good basis for further research; it is therefore recommended that future Colombian anthropometric surveys be conducted for children and disabled Colombian population. An extensive and accurate anthropometric study of Latin American male and female populations is also needed.

Anthropometrists normally collect statistics for a particular sex and race. In most instances, a mixture of individuals with different ethnicities is the target population. Therefore, to design or evaluate anthropometric systems, relevant anthropometric data should be collected for a collective mixture of populations and not for particular individuals. Currently, in the U.S. a substantial proportion of workers are Hispanic, Asians or from the middle east. According to the 1990 U.S. Census, Hispanics of all races, who present 24 million people and 9 % of the population today, would climb to 81 million and 21 % by 2050 and become the biggest minority group. Hence, further anthropometric

studies involving the Hispanic and other populations living and working in the U.S., are

suggested.

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Appendix A

Measurement Procedures Manual

1- Introduction.

Due to the lack of a comprehensive and representative source of Colombian anthropometric data, a survey will be conducted, in order to assemble an anthropometric data set which will be sufficiently comprehensive and accurate for general design and estimation applications.

The survey will be carried out in the ergonomics laboratory at Florida International University, Miami, Florida. A set of 20 body dimensions, in standing and sitting positions, will be taken from a sample of 134 Colombian adults, male and female, living in south Florida and ages ranged 20-64 years. Subjects will participate and selected on a voluntary and random basis respectively, covering a total mix of Colombian geographical regions. Dimensions will be chosen according to their relevance in general design proposes and in international anthropometric standard lists. Measurements procedures and techniques to be followed in the survey will be determined after a wide review of literature; consequently, a manual of procedures will be compiled to be used by the measurement team as a reference book during the training period and in the measuring session. A

special designed grid system and other traditional anthropometric instruments will be used throughout the survey. Measurements will be taken by a trained team, and anthropometric data will be recorded in a special form. A detailed statistical analysis (range, mean, standard deviation, coefficient of variation, standard error and percentiles) will be carried out using a statistical software, and its results will be presented, discussed, and compared with those of other populations. Finally, survey comments and conclusions will be drawn.

This manual of measurement procedures is divided into four parts: The first, introduction, describes the survey and manual aims. The second describes in detail, for each dimension, the following: (a) dimension definition, (b) landmarks definitions, (c) position of the subject, (d) position of measurer, (e) procedure to be followed in taking measurement, and (f) remarks. The third part, is composed of an anatomical and anthropometric terminology glossary, and the fourth shows an illustrated glossary of the anatomical planes, orientations and landmarks.

2- Measurement Procedures.

1- STATURE

Definition: The height of the top of the head .

Landmarks: The most superior part of the skull, (vertex), and the inferior surfaces of the feet, (soles or plantar surfaces).

Instruments: Movable anthropometer.

Position of subject: The subject stands on a flat surface, and his or her body weight is evenly distributed on both feet, heels together as closely as possible, legs and torso straight without stiffness and head erect with the line of vision parallel to the floor. The

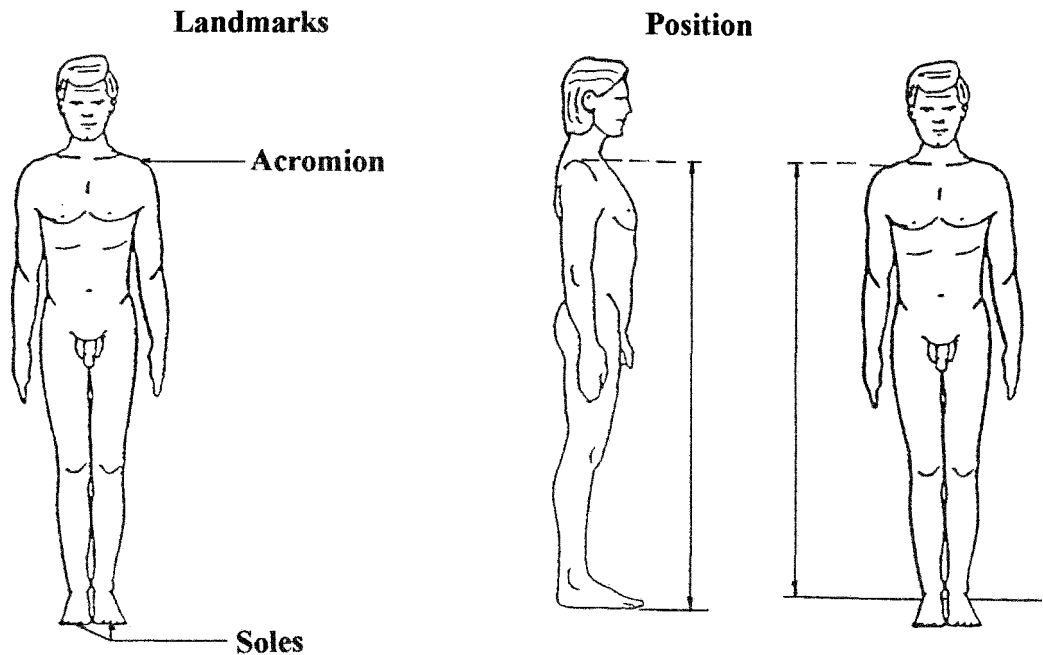arms hang straight but loosely at the sides with the palms alongside but no touching the thighs. Subject remains in this position while the measurement is taken.

Position of measurer: The measurer stands at the subject's right side.

Procedure: The anthropometer's lower part is set on the floor surface while the upper part is hold and balance in a vertical position in the measurer's right hand. The moving arm of the anthropometer is lowered with the left hand until the blade point rest onto specified landmark (vertex). The hair texture is taken into consideration when exploring the top of the head, and sufficient pressure is used to bring the blade point piece of the anthropometer to the level of the vertex. When the subject and measurer are also positioned, the subject is instructed to take a deep breath, and the measurement is made just before the subject exhales. The measurer should observe the level of the anthropometer blade without parallax; hence a small stool may be required. The measurement is recorded to the nearest millimeter.

Remarks: Measurement is repeated three times. The subject has to step off after the first measurement, and take position again in between measurements. It is important that the recorder observe both the position of the subject to avoid slouching and also the position of the anthropometer to ensure that it is vertical and the blade is brought down in the midline of the head. If too much pressure is applied to the anthropometer blade, it may slide to one side off the vertex.

Landmarks   **Position**
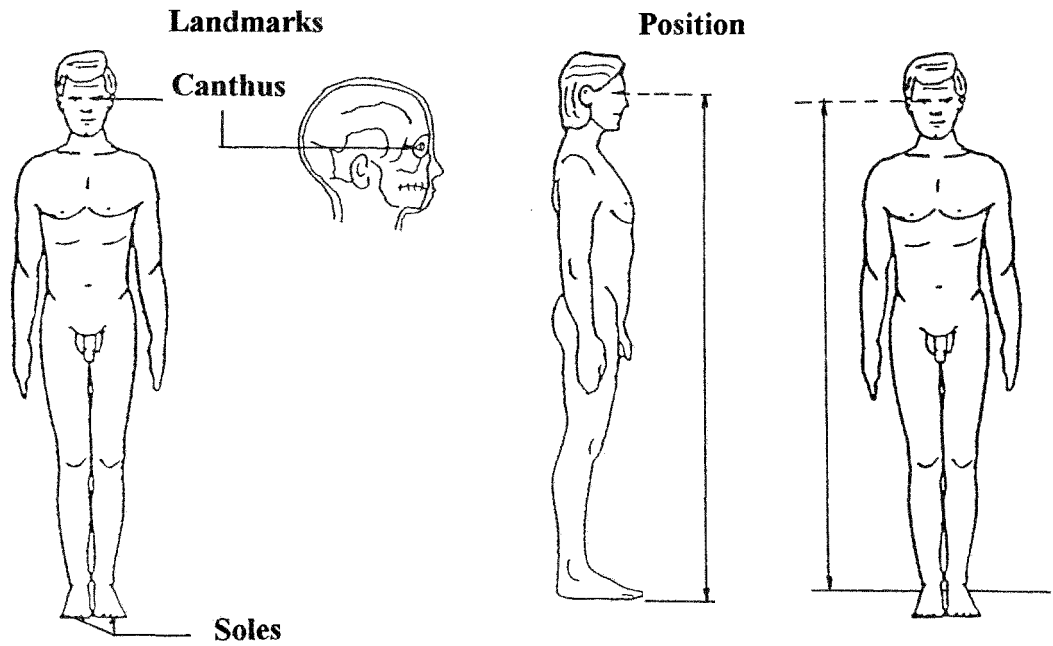
Canthus

Soles

Definition: The height of the inner corner of the eye.

Landmarks: The inner corner of the eye,(canthus), and the inferior surfaces of the feet,

(soles or plantar surfaces).

Instruments: Movable anthropometer.

Position of subject: The subject stands on a flat surface, and his or her body weight is

evenly distributed on both feet, heels together as closely as possible, legs and torso

straight without stiffness and head erect with the line of vision parallel to the floor. The
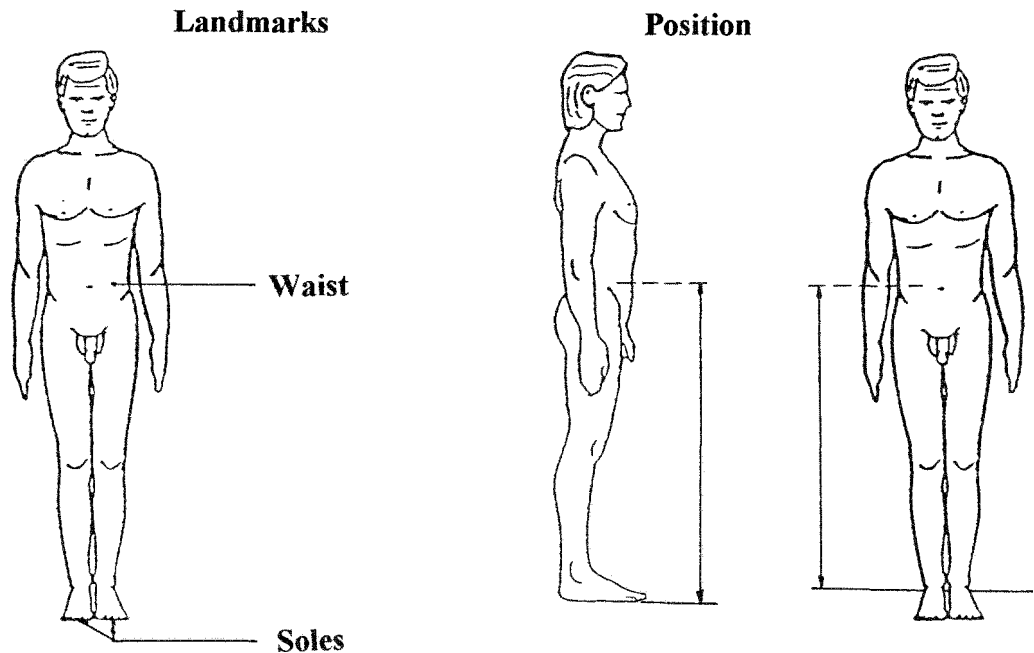
arms hang straight but loosely at the sides with the palms alongside but no touching the

thighs. Subject remains in this position while the measurement is taken.

Position of measurer: The measurer stands at the subject's right side.

Procedure: The anthropometer's lower part is set on the floor surface while the upper part is hold and balance in a vertical position in the measurer's right hand. The moving arm of the anthropometer is lowered with the left hand until the blade point rests onto specified landmark (inner cantus of the eye). When the subject and measurer are also positioned, the subject is instructed to take a deep breath, and the measurement is made just before the subject exhales. The measurer should observe the level of the anthropometer blade without parallax; hence a small stool may be required. The measurement is recorded to the nearest millimeter.

Remarks: Measurement is repeated three times. The subject has to step off after the first measurement, and take position again in between measurements. It is important that the recorder observe both the position of the subject to avoid slouching and also the position of the anthropometer to ensure that it is vertical and the blade is brought down onto the specified landmark.

3- SHOULDER HEIGHT

Landmarks

Acromion

Soles

Position

Definition: The height of the acromion.

Landmarks: The most prominent posterior lateral bony of the spine of the escapula or

point of the shoulder, (acromion), and the inferior surfaces of the feet, (soles or plantar

surfaces).

Instruments: Movable anthropometer.

Position of subject: The subject stands on a flat surface, and his or her body weight is

evenly distributed on both feet, heels together as closely as possible, legs and torso

straight without stiffness and head erect with the line of vision parallel to the floor. The

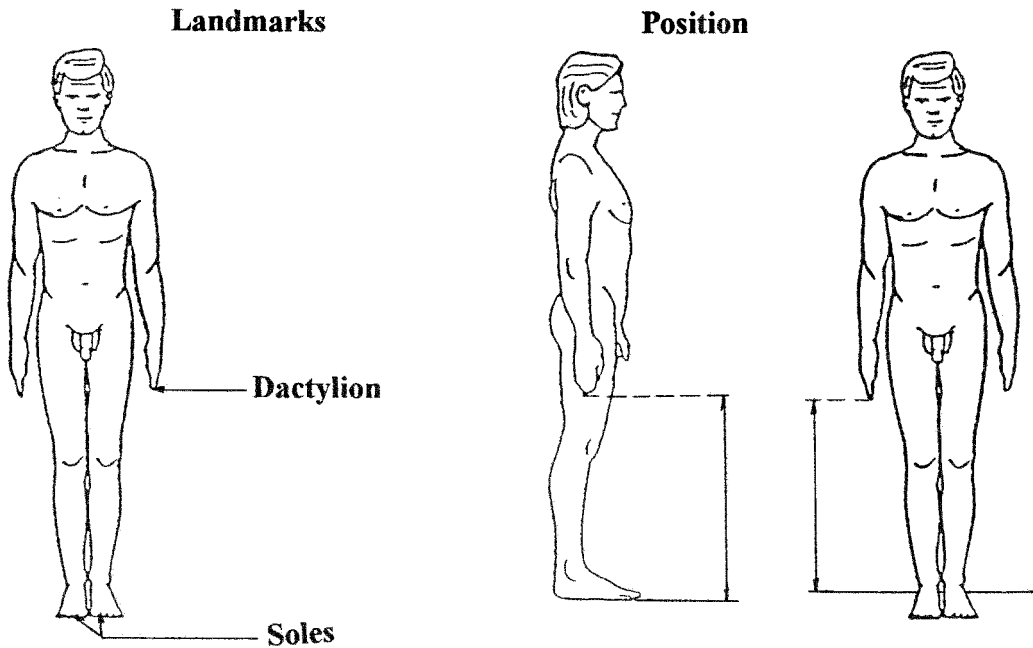arms hang straight but loosely at the sides with the palms alongside but no touching the thighs. Subject remains in this position while the measurement is taken.

Position of measurer: The measurer stands at the subject's right side facing landmark as placed.

Procedure: The anthropometer's lower part is set on the floor surface while the upper part is hold and balance in a vertical position in the measurer's right hand. The moving arm of the anthropometer is lowered with the left hand until the blade point rests onto specified landmark (most upper prominent bony of the acromion). When the subject and measurer are also positioned, the subject is instructed to take a deep breath, and the measurement is made just before the subject exhales. The measurer should observe the level of the anthropometer blade without parallax. The measurement is recorded to the nearest millimeter.

Remarks: Measurement is repeated three times. The subject has to step off after the first measurement, and take position again in between measurements. It is important that the recorder observe both the position of the subject to avoid slouching and also the position of the anthropometer to ensure that it is vertical and the blade point is brought down onto the specified landmark. If too much pressure is applied to the anthropometer blade, it may slide to one side off the landmark.

4- WAIST HEIGHT

Landmarks   **Position**

Waist

Soles

Definition: The height of waist level.

Landmarks: The middle point of the body between the ribs and the hips, (waist), and the

inferior surfaces of the feet, (soles or plantar surfaces).

Instruments: Movable anthropometer.

Position of subject: The subject stands on a flat surface, and his or her body weight is

evenly distributed on both feet, heels together as closely as possible, legs and torso

straight without stiffness and head erect with the line of vision parallel to the floor. The
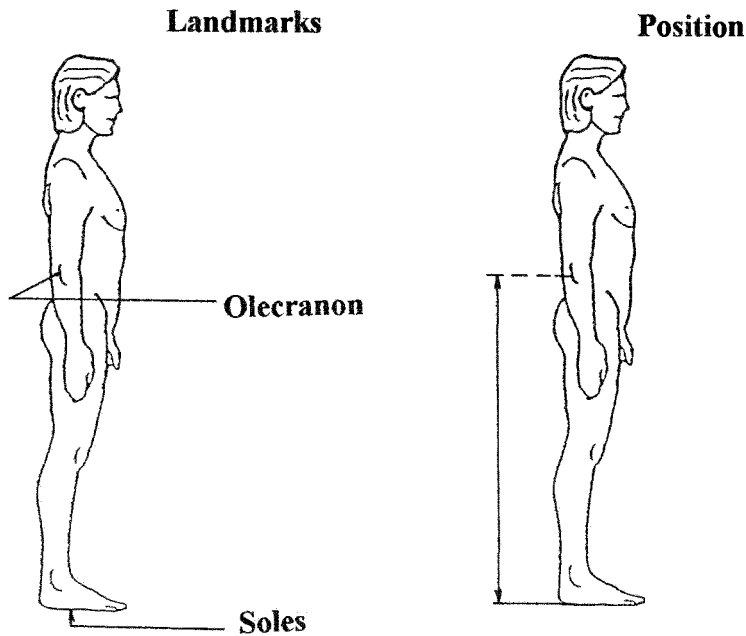
arms hang straight but loosely at the sides with the palms alongside but no touching the

thighs. Subject remains in this position while the measurement is taken.

Position of measurer: The measurer stands at the subject's right side facing landmark as placed.

Procedure: The anthropometer's lower part is set on the floor surface while the upper part is hold and balance in a vertical position in the measurer's right hand. The moving arm of the anthropometer is lowered with the left hand until the blade point rests onto specified landmark (waist). When the subject and measurer are also positioned, the subject is instructed to take a deep breath, and the measurement is made just before the subject exhales. The measurement is recorded to the nearest millimeter.

Remarks: Measurement is repeated three times. The subject has to step off after the first measurement, and take position again in between measurements. It is important that the recorder observe both the position of the subject to avoid slouching and also the position of the anthropometer to ensure that it is vertical and the blade point is brought down onto the specified landmark.

5- DACTYLION HEIGHT

Landmarks   **Position**

Dactylion

Soles

Definition: The height of the tip of the middle finger measured with the arm, hand, and finger extended downward.

Landmarks: The tip of the distal phalange of the middle finger, (dactylion), and the inferior surfaces of the feet, (soles or plantar surfaces).

Instruments: Movable anthropometer.

Position of subject: The subject stands on a flat surface, and his or her body weight is evenly distributed on both feet, heels together as closely as possible, legs and torso straight without stiffness and head erect with the line of vision parallel to the floor. The

arms hang straight but loosely at the sides with the palms alongside but no touching the thighs. Subject remains in this position while the measurement is taken.

Position of measurement: The measurer usually find it most convenient to sit in front of the subject.

Procedure: The anthropometer's lower part is set on the floor surface while the upper part is hold and balance in a vertical position in the measurer's right hand. The moving arm of the anthropometer is lowered with the left hand until the blade point rests onto specified landmark (tip of the middle finger). When the subject and measurer are also positioned, the subject is instructed to take a deep breath, and the measurement is made just before the subject exhales. The measurement is recorded to the nearest millimeter.

Remarks: Measurement is repeated three times. The subject has to step off after the first measurement, and take position again in between measurements. It is important that the recorder observe both the position of the subject to avoid slouching and also the position of the anthropometer to ensure that it is vertical and the blade point is brought down onto the specified landmark.

6- ELBOW HEIGHT

Olecranon

Soles

Definition: The height of radiale.

Landmarks: The most posterior point of the olecranon and the inferior surfaces of the feet, (soles or plantar surfaces).

Instruments: Movable anthropometer.

Position of subject: The subject stands on a flat surface, and his or her body weight is evenly distributed on both feet, heels together as closely as possible, legs and torso straight without stiffness and head erect with the line of vision parallel to the floor. The arms hang straight but loosely at the sides with the palms alongside but no touching the

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thighs. Subject remains in this position while the measurement is taken.

Position of measurer: The measurer stands at the subject's right side facing landmark as placed.

Procedure: The anthropometer's lower part is set on the floor surface while the upper part is hold and balance in a vertical position in the measurer's right hand. The moving arm of the anthropometer is lowered with the left hand until the blade point rests onto specified landmark (most posterior point of the olecranon). When the subject and measurer are also positioned, the subject is instructed to take a deep breath, and the measurement is made just before the subject exhales. The measurement is recorded to the nearest millimeter.

Remarks: Measurement is repeated three times. The subject has to step off after the first measurement, and take position again in between measurements. It is important that the recorder observe both the position of the subject to avoid slouching and also the position of the anthropometer to ensure that it is vertical and the blade point is brought down onto the specified landmark.

7- HIP BREADTH

Landmarks   **Position**
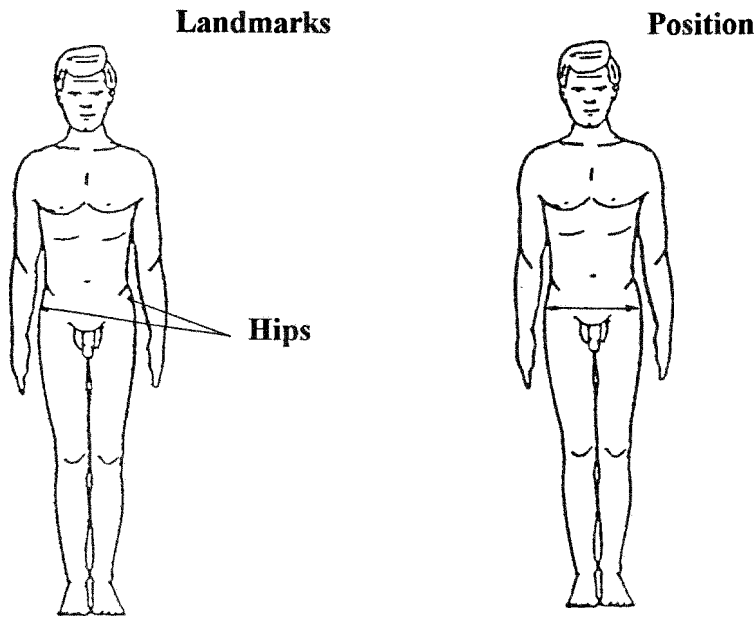
Hips

Definition: The maximum breadth of the lower torso.

Landmarks: The most lateral borders of the hips.

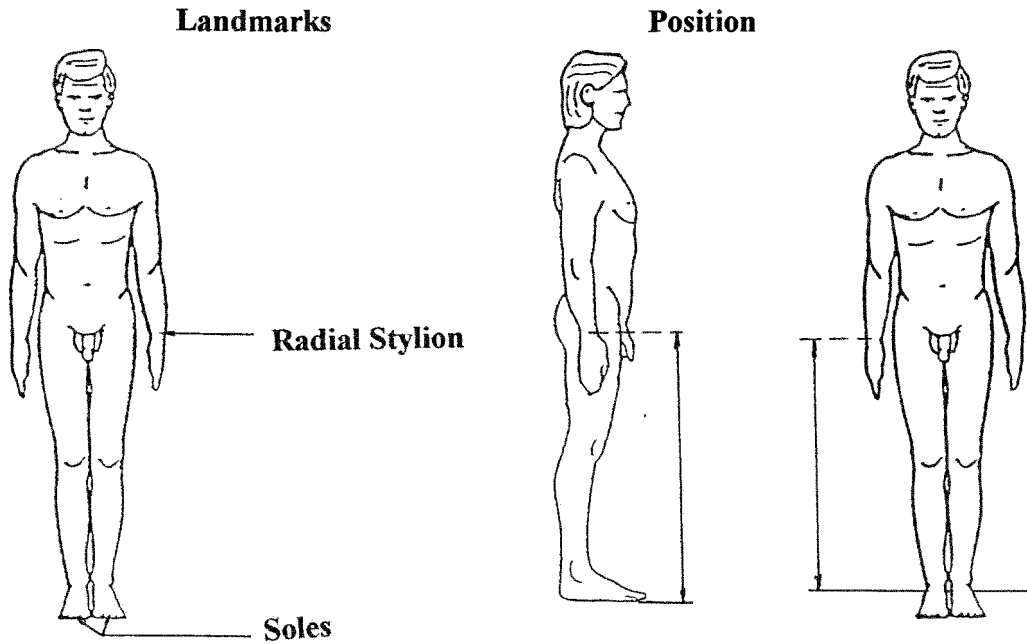**Instruments:** Caliper or anthropometer configured as a sliding beam caliper.

Position of subject: The subject stands on a flat surface, and his or her body weight is evenly distributed on both feet, heels together as closely as possible, legs and torso straight without stiffness and head erect with the line of vision parallel to the floor. The arms need to be away from the area of measurement, preferably folded across the chest. Subject remains in this position while the measurement is taken.

Position of measurer: The measurer stands back of the subject.

Procedure: The caliper or anthropometer is hold so that its blades are between the index and middle fingers and resting on the base of the thumb. The fixed arm is positioned to make firm contact with the most prominent lateral bony prominence of the left hip, while the sliding arm is aligned with the most distal palpable point of the right hip. The measurement is recorded to the nearest millimeter.

Remarks: Measurement is repeated three times. The subject has to step off after the first measurement, and take position again in between measurements. It is important that the recorder observe both the position of the subject to avoid slouching and also the position of the anthropometer to ensure that blade point is brought onto the specified landmark.

8- WRIST HEIGHT

Landmarks   **Position**

Radial Stylion

Soles

Definition: The height of stylion.

Landmarks: The most palpable point of the distal end of the radious, (radial stylion), and the inferior surfaces of the feet, (soles or plantar surfaces).

Instruments: Movable anthropometer.

Position of subject: The subject stands on a flat surface, and his or her body weight is evenly distributed on both feet, heels together as closely as possible, legs and torso straight without stiffness and head erect with the line of vision parallel to the floor. The arms hang straight but loosely at the sides with the palms alongside but no touching the

thighs. Subject remains in this position while the measurement is taken.

Position of measurer: The measurer stands at the subject's right side facing landmark as placed.

Procedure: The anthropometer's lower part is set on the floor surface while the upper part is hold and balance in a vertical position in the measurer's right hand. The moving arm of the anthropometer is lowered with the left hand until the blade point rests onto specified landmark (most palpable point of the radial stylion). When the subject and measurer are also positioned, the subject is instructed to take a deep breath, and the measurement is made just before the subject exhales. The measurement is recorded to the nearest millimeter.

Remarks: Measurement is repeated three times. The subject has to step off after the first measurement, and take position again in between measurements. It is important that the recorder observe both the position of the subject to avoid slouching and also the position of the anthropometer to ensure that it is vertical and the blade point is brought down onto the specified landmark.

9- UPPER LIMB LENGTH

Landmarks   **Position**
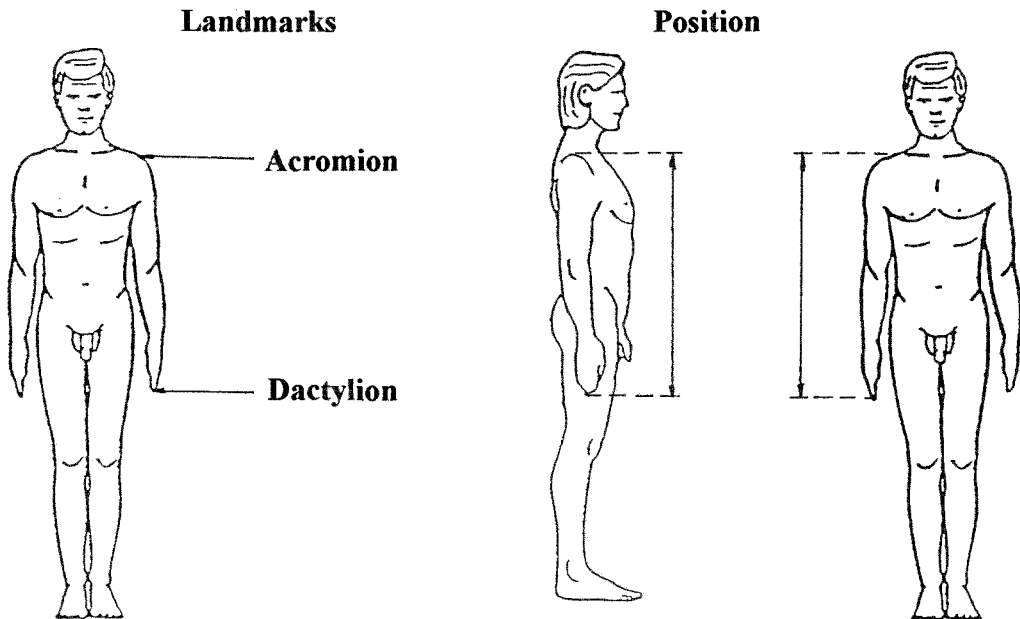
Definition: The vertical distance from acromion to the tip of the middle finger.

Landmarks: The most prominent posterior lateral bony of the the spine of the scapula or point of the shoulder, (acromion), and the tip of the distal phalange of the middle finger, (dactylion).

Instruments: Caliper or anthropometer configured as a sliding beam caliper.

Position of the subject: The subject stands on a flat surface, and his or her body weight is evenly distributed on both feet, heels together as closely as possible, legs and torso straight without stiffness and head erect with the line of vision parallel to the floor. The

arms hang straight but loosely at the sides with the palms alongside but no touching the thighs. Subject remains in this position while the measurement is taken.

Position of the measurer: The measurer stands at the subject's right side facing landmark as placed.

Procedure: The fixed arm of the beam caliper is placed to make firm contact with the most prominent posterior lateral bony prominence of the shoulder joint (acromion), while the sliding arm of the caliper is shifted to make contact with the fleshy tip of the middle finger of the hand (dactylion). The measurement is recorded to the nearest millimeter.

Remarks: Measurement is repeated three times. The subject has to step off after the first measurement, and take position again in between measurements. It is important that the recorder observe both the position of the subject to avoid slouching and also the position of the anthropometer to ensure that it is positioned onto the specified landmark.

Landmarks	Position
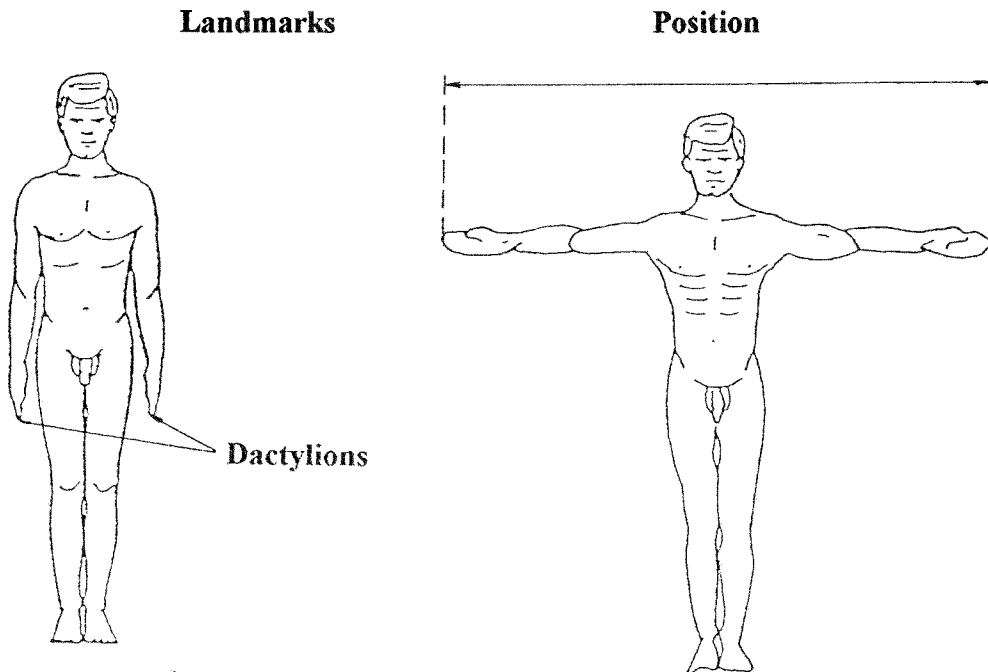
Dactylions

Definition: The distance between the tips of the right and left middle fingers when the subject's arms are maximally extended laterally.

Landmarks: The tips of the right and left distal phalanges of the middle fingers, (dactylions).

Instruments: Measure tape, a flat surface (usually two cross walls) and a millimeter scale (millimeter paper)..

Position of subject: The subject stands with the feet together and so that his or her back is against the wall. The arms are outstretched laterally and maximally at the level of the

shoulders, in contact with the wall, and with the palms facing forwards. The tip of the middle (longest) finger (excluding the fingernail) of the left hand is kept in contact with the corner at the cross wall.

Position of measurer: The measurer stands in front of the subject.

Procedure: A piece of millimeter paper is fastened on the wall in such position that. it form a tape measure on the wall with zero in the corner at the cross wall. With the subject properly positioned, the reading can be taken directly off the paper. The paper, of course, would be subject to wear and tear, and would be probably be influenced by humidity. A plastic cover over properly affixed or laminated millimeter paper would reduce wear and tear effects. The measurement is recorded to the nearest millimeter. Occasionally a small stool may be required to make this measurement in tall subjects.

Remarks: Measurement is repeated three times. The subject has to step off after the first measurement, and take position again in between measurements.

11- VERTICAL GRIP REACH

Landmarks	Position
Pointer Center	
Soles	
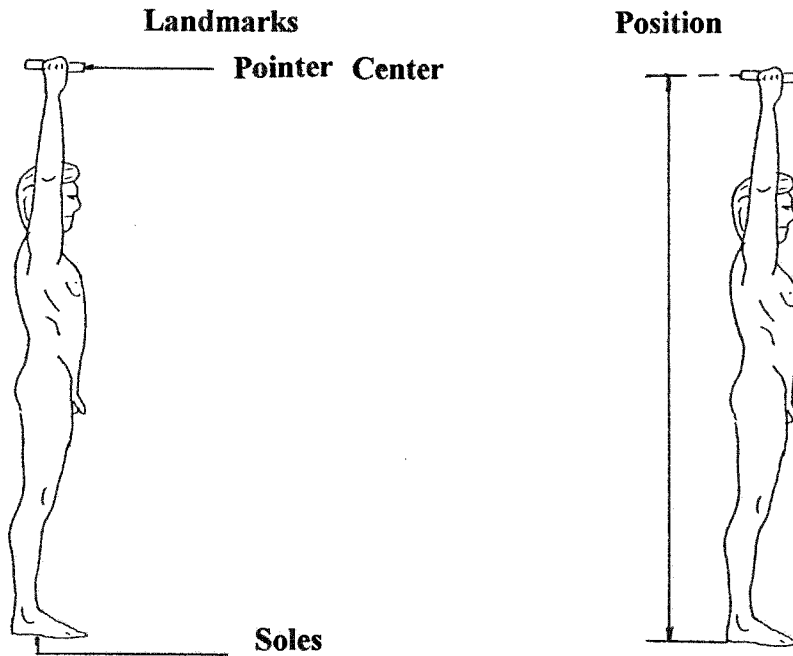
Definition: The height of a pointer held horizontal in the subject's fist when the arm is maximally extended upward.

Landmarks: The center of the cylindrical pointer and the inferior surfaces of the feet, (soles or plantar surfaces).

Instruments: Measure tape, a flat surface (wall) and a millimeter scale (millimeter paper).

Position of subject: The subject stands on a flat surface, and his or her body weight is evenly distributed on both feet, heels together as closely as possible, legs and torso straight without stiffness and head erect with the line of vision parallel to the floor and so

that his or her back is against the wall. A pointer is held horizontal in the subject's right fist and the right arm is maximally extended upward with the palms facing inwards. Subject remains in this position while the measurement is taken.

Position of measurer: The measurer stands at the subject's right side.

Procedure: A piece of millimeter paper is fastened on the wall in such position that it form a tape measure on the wall with zero in the floor. When the subject and measurer are also positioned, the subject is instructed to take a deep breath, and the measurement is made just before the subject exhales. The reading can be taken directly off the paper. The paper, of course, would be subject to wear and tear, and would be probably be influenced by humidity. A plastic cover over properly affixed or laminated millimeter paper would reduce wear and tear effects. The measurement is recorded to the nearest millimeter. Occasionally a small stool may be required to make this measurement in tall subjects.

Remarks: Measurement is repeated three times. The subject has to step off after the first measurement, and take position again in between measurements.

12- SITTING HEIGHT
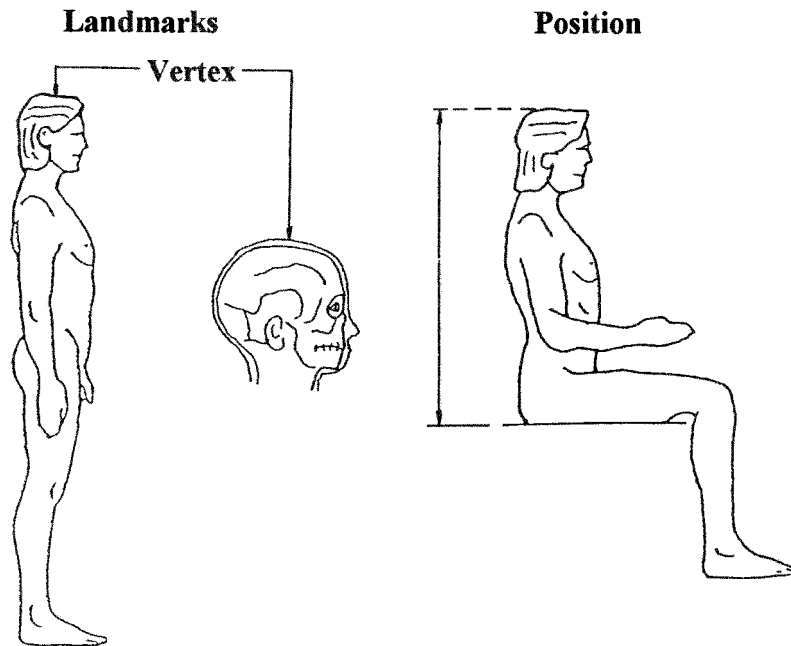
Landmarks

— Vertex —

Position

Definition: The height, from the sitting surface, to the top of the head.

Landmarks: The most superior part of the skull, (vertex), and the sitting surface.

Instruments: Movable anthropometer and table. Table should be sufficiently high so that subject's legs hang freely.

Position of subject: The subject sits on the table with the legs hanging unsupported over the edge of the table and with the hands resting on the thighs. The knees are directed straight ahead. The backs of the knees are near the edge of the table but not in contact with it. The subject sits as erect as possible, with the path of vision parallel to the plane of

the floor. In positioning, it is useful to approach the subject from the left side and to apply gentle pressure simultaneously with the right hand over the lumbar area and with the left hand on the superior part of the sternum. This reinforces the erect position.

Position of measurer: The measurer stands at the subject's left side.

Procedure: The lower half of the anthropometer is set on the table surface, and it is positioned vertically in the midline behind the subject so that it nearly touches the sacral and interscapular regions. The measurer's left hand is placed under the subject's chin to assist in holding the proper position. The left hand moves the blade of the anthropometer onto the vertex (the most superior point on the head in the sagittal plane). When the subject and measurer are so positioned, the subject is instructed to take a deep breath, and the measurement is made just before the subject exhales. Firm pressure is applied to compress the hair. The measurer should observe the level of the anthropometer blade without parallax; hence, a small stool may be required. The measurement is recorded to the nearest millimeter.

Remarks: Measurement is repeated three times. The subject has to stand up after the first measurement, and take position again in between measurements. It is important that the recorder observe both the position of the subject to avoid slouching and also the position of the anthropometer to ensure that it is vertical and the blade is brought down onto the specified landmark. If too much pressure is applied to the anthropometer blade, it may

slide to one side off the vertex. It is important that the subject's arms rest relaxed on the thighs. The subjects should not place their hands on the side of the table and push themselves erect.

13- SITTING EYE HEIGHT
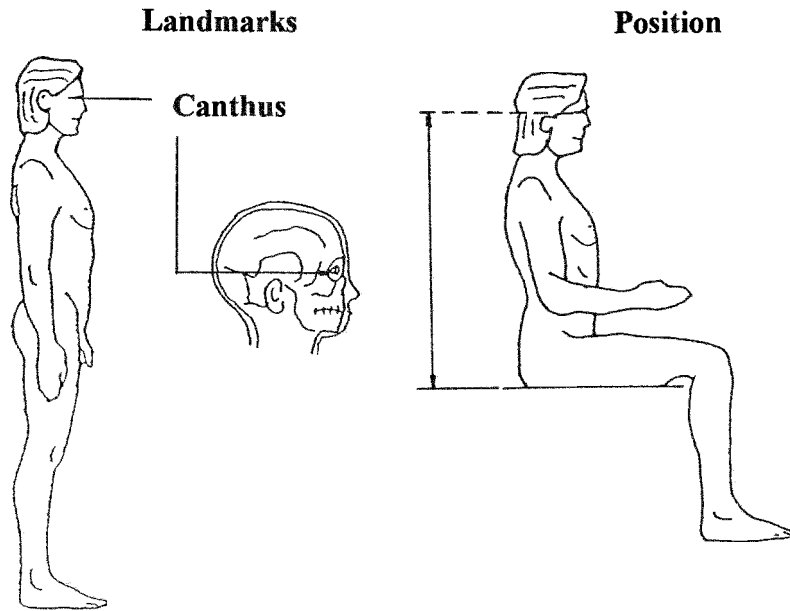
Landmarks

Canthus

Position

Definition: The height of the inner corner of the eye.

Landmarks: The inner corner of the eye, (canthus), and the sitting surface.

Instruments: Movable anthropometer and table. Table should be sufficiently high so that

subject's legs hang freely.

Position of subject: The subject sits on the table with the legs hanging unsupported over

the edge of the table and with the hands resting on the thighs. The knees are directed

straight ahead. The backs of the knees are near the edge of the table but not in contact

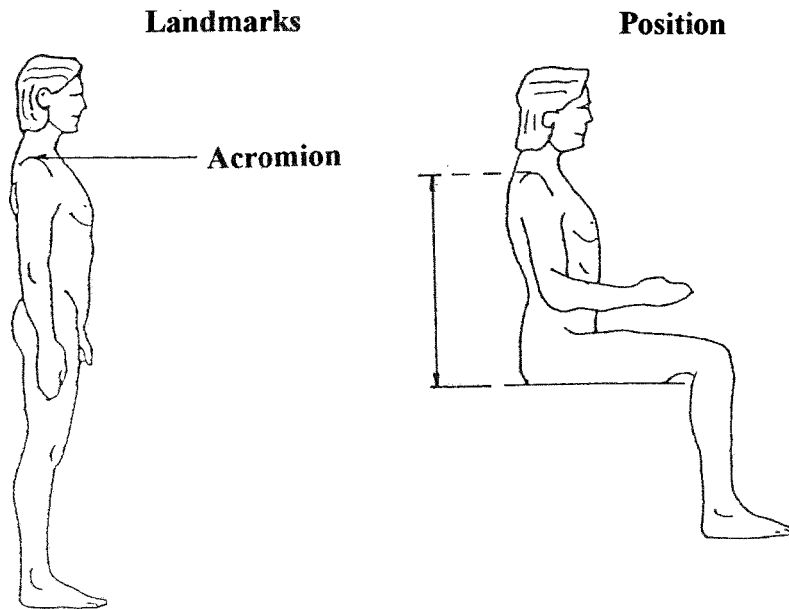with it. The subject sits as erect as possible, with the path of vision parallel to the plane of

the floor. In positioning, it is useful to approach the subject from the left side and to apply gentle pressure simultaneously with the right hand over the lumbar area and with the left hand on the superior part of the sternum. This reinforces the erect position.

Position of measurer: The measurer stands in front of subject.

Procedure: The lower half of the anthropometer is set on the table surface, and it is hold and balance in a vertical position in the measure's right hand. The measurer's left hand is placed under the subject's chin to assist in holding the proper position, then the left hand moves the blade of the anthropometer onto the specified landmark (inner corner of the eye). When the subject and measurer are so positioned, the subject is instructed to take a deep breath, and the measurement is made just before the subject exhales. The measurer should observe the level of the anthropometer blade without parallax. The measurement is recorded to the nearest millimeter.

Remarks: Measurement is repeated three times. The subject has to stand up after the first measurement, and take position again in between measurements. It is important that the recorder observe both the position of the subject to avoid slouching and also the position of the anthropometer to ensure that it is vertical and the blade is brought down onto the specified landmark. It is important that the subject's arms rest relaxed on the thighs. The subjects should not place their hands on the side of the table and push themselves erect.

14- SITTING SHOULDER HEIGHT.

Landmarks   **Position**

Definition: The height of acromion above the sitting surface.

Landmarks: The most prominent posterior lateral bony of the supine of the scapula or

point of the shoulder, (acromion), and the sitting surface.

Instruments: Movable anthropometer and table. Table should be sufficiently high so that

subject's legs hang freely.

Position of subject: The subject sits on the table with the legs hanging unsupported over

the edge of the table. The knees are directed straight ahead. The backs of the knees are

near the edge of the table but not in contact with it. The subject sits as erect as possible,

with the path of vision parallel to the plane of the floor. The subject's arms are vertical, with the elbows resting lightly against the sides of the body. The elbows are flexed to about 90 degrees so that the forearms and the supinated hands are extended forwards horizontally. The fingers are together and extended in the direction of the longitudinal axes of the forearms. In positioning, it is useful to approach the subject from the left side and to apply gentle pressure simultaneously with the right hand over the lumbar area and with the left hand on the superior part of the sternum. This reinforces the erect position. Subject remains in this position while the measurement is taken.

Position of measurer: The measurer stands at the subject's left side.

Procedure: The lower half of the anthropometer is set on the table surface, and it is hold and balance in a vertical position in the measure's right hand. The measurer's left hand is placed under the subject's chin to assist in holding the proper position, then the left hand moves the blade of the anthropometer onto the specified landmark (most prominent lateral bony prominence of the shoulder joint). When the subject and measurer are so positioned, the subject is instructed to take a deep breath, and the measurement is made just before the subject exhales. The measurer should observe the level of the anthropometer blade without parallax. The measurement is recorded to the nearest millimeter.

Remarks: Measurement is repeated three times. The subject has to stand up after the first measurement, and take position again in between measurements. It is important that the

recorder observe both the position of the subject to avoid slouching and also the position of the anthropometer to ensure that it is vertical and the blade is brought down onto the specified landmark. If too much pressure is applied to the anthropometer blade, it may slide to one side off the landmark. It is important that the subject's arms rest relaxed on the thighs. The subjects should not place their hands on the side of the table and push themselves erect.

15- BUTTOCK KNEE LENGTH

Landmarks

Position

Buttock Protrusion
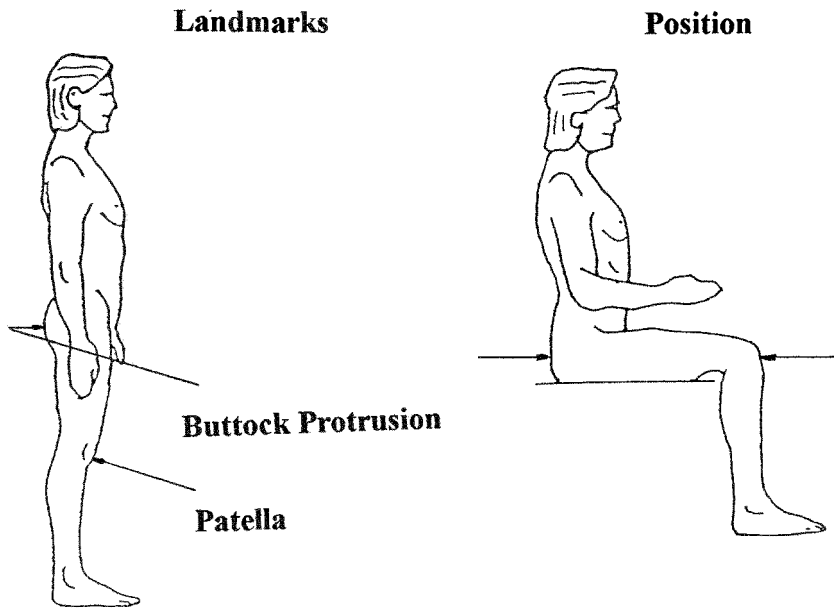
Patella

Definition: The horizontal distance from the rearmost surface of the buttocks to the front of the kneecaps.

Landmarks: The most posterior prominence of the gluteal region or buttock and the anterior surface of the kneecap, (patella).

Instruments: Caliper or anthropometer configured as sliding beam caliper ,table and adjustable footrest.

Position of subject: The subject sits erect on a cushionless flat surface (table), feet on an adjustable footrest so that the knees are flexed to 90 degrees, the long axis of the thighs

parallel. The trunk is erected without stiffness and the head is also erect with the path of vision parallel to the plane of the floor. The subject's arms are vertical, with the elbows resting lightly against the sides of the body. The elbows are flexed to about 90 degrees so that the forearms and the supinated hands are extended forwards horizontally. The fingers are together and extended in the direction of the longitudinal axes of the forearms. In positioning, it is useful to approach the subject from the left side and to apply gentle pressure simultaneously with the right hand over the lumbar area and with the left hand on the superior part of the sternum. This reinforces the erect position. Subject remains in this position while the measurement is taken.

Position of measurer: The measurer stands at the subject's right side.

Procedure: The caliper or anthropometer is hold so that its blades are between the index and middle fingers and resting on the base of the thumb. The fixed arm is positioned to make firm contact with the most prominent lateral bony prominence of the buttoks, while the sliding arm is aligned with the most distal palpable point of the kneecaps (patella). The measurement is recorded to the nearest millimeter.

Remarks: Measurement is repeated three times. The subject has to stand up after the first measurement, and take position again in between measurements. It is important that the recorder observe both the position of the subject to avoid slouching and also the position of the anthropometer to ensure that it is positioned onto the specifies landmark.

Landmarks   **Position**
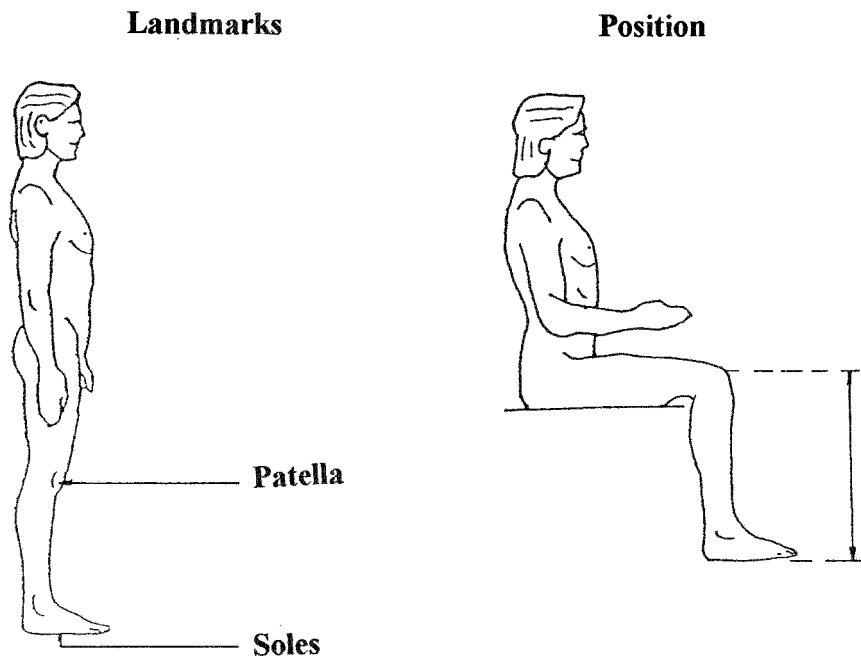
Patella

Soles

Definition: The height, from the footrest surface, of the musculature just above the knee.

Landmarks: The most superior prominence bony of the kneecap, (patella), and the inferior surfaces of the feet, (soles or plantar surfaces).

Instruments: Movable anthropometer ,table and adjustable footrest.

Position of subject: The subject sits erect on a cushionless flat surface (table), feet on an adjustable footrest so that the knees are flexed to 90 degrees, the long axis of the thighs parallel. The trunk is erected without stiffness, head is also erect with the path of vision parallel to the plane of the floor and hands are rested on the thighs. In positioning, it is

useful to approach the subject from the left side and to apply gentle pressure simultaneously with the right hand over the lumbar area and with the left hand on the superior part of the sternum. This reinforces the erect position. Subject remains in this position while the measurement is taken.

Position of measurer: The measurer stands at the subject's right side.

Procedure: The lower half of the anthropometer is set on the footrest surface, and it is hold and balance in a vertical position in the measure's right hand. The measurer's left hand moves the sliding blade of the anthropometer onto the specified landmark (musculature just above the knee). The measurement is recorded to the nearest millimeter.

Remarks: Measurement is repeated three times. The subject has to stand up after the first measurement, and take position again in between measurements. It is important that the recorder observe both the position of the subject to avoid slouching and also the position of the anthropometer to ensure that it is positioned onto the specified landmark.

17- SHOULDER BREADTH

Landmarks   **Position**
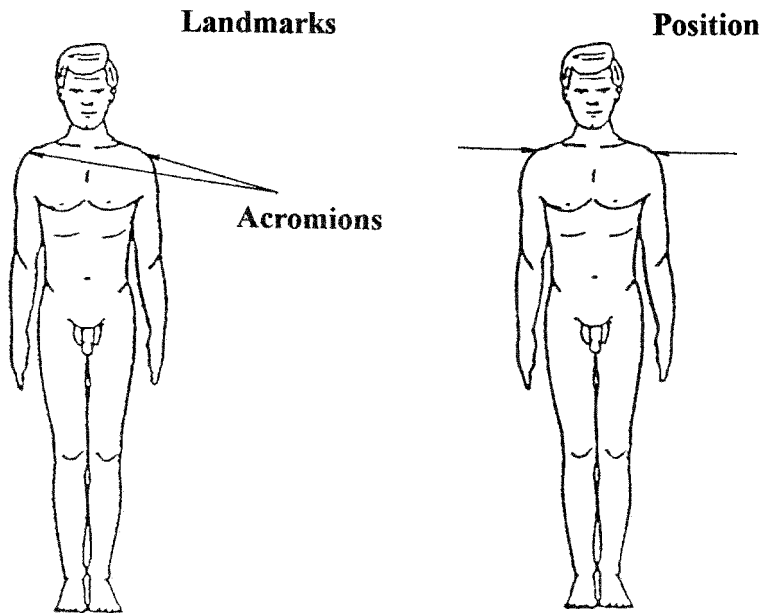
Acromions

Definition: The distance across the shoulders from right to left acromion.

Landmarks: Left and right most prominent posterior lateral bony of the supine of the scapula, point of the shoulder, (acromions).

Instruments: Caliper or anthropometer configured as sliding beam caliper.

Position of subject: The subject stands, because sitting interferes with the posture required for measurement. The subject stands on a flat and his or her body weight is evenly distributed on both feet, heels together as closely as possible, legs and torso straight without stiffness and head erect with the line of vision parallel to the floor. The

arms hang straight but loosely at the sides with the palms alongside but no touching the thighs. Subject remains in this position while the measurement is taken.

Position of measurer: The measurer stands back of the subject.

Procedure: Standing directly behind the subject, the measurer runs his hands from the base of the neck outwards to the tips of the shoulders, relaxing any tension. The most lateral borders of the acromial processes are palpated and, holding the anthropometer or caliper so that its blades are between the index and middle fingers and resting on the base of the thumb, the blades are applied firmly to the most lateral borders of the acromial processes. The width is read to the nearest millimeter.

Remarks: Measurement is repeated three times. The subject has to step off after the first measurement, and take position again in between measurements. It is important that the recorder observe both the position of the subject to avoid slouching and also the position of the anthropometer to ensure that it is positioned onto the specified landmark. If too much pressure is applied to the anthropometer blade, it may slide to one side off the landmark.

Landmarks
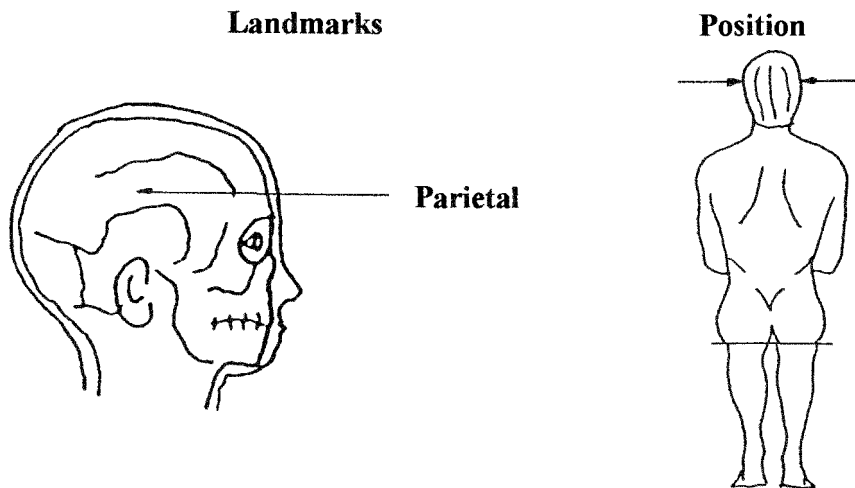
Position

Parietal

Definition: The maximum breadth of the head.

Landmarks: The most lateral points of the parietal bones on each side of the skull.

Instruments: Sliding or spreading caliper.

Position of subject: The measurement is made with the subject in a natural standing or sitting position. The subject's head should be held erect with the line of vision parallel to the floor.

Position of measurer: The measurer stands in front of the subject.

Procedure: Upon palpation of the most lateral points of the parietal bones (eurion) on

each side of the head, the measurer places the caliper tips directly on the landmarks, with his or her fingers just beneath the caliper tips to prevent them from slipping .Measurement is made with caliper tips in a horizontal plane. When the subject and measurer are so positioned, the subject is instructed to take a deep breath, and the measurement is made just before the subject exhales. The measurement is recorded to the nearest millimeter.

Remarks: Measurement is repeated three times. The subject has to step off after the first measurement, and take position again in between measurements. It is important that the recorder observe both the position of the subject to avoid slouching and also the position of the caliper to ensure that it is positioned onto the specified landmark.

19- CHEST (BUST) DEPTH

Landmarks   Position

Bust Point
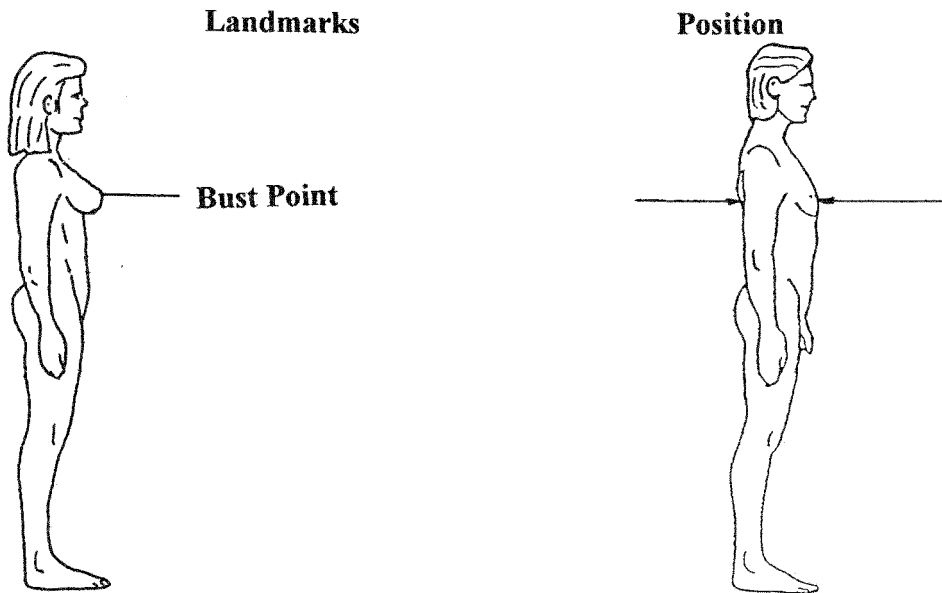
Definition:

- Chest: The depth of the torso measured at nipple level.

- Bust: The horizontal distance from the subject's back to the tip of her bra.

Landmarks: The most anterior prominence of the breast at the nipple level and the most

posterior aspect of the thorax.

Instruments: Sliding or spreading caliper.

Position of subject: The subject stands on a flat surface, and his or her body weight is

evenly distributed on both feet, heels together as closely as possible, legs and torso

straight without stiffness and head erect with the line of vision parallel to the floor. The arms hang straight but loosely at the sides with the palms alongside but no touching the thighs. Subject remains in this position while the measurement is taken.

Position of measurer: The measurer stands at the subject's right side.

Procedure: The measurer places the caliper tips directly on the landmarks, with his or her fingers just beneath the caliper tips to prevent them from slipping .Measurement is made with caliper tips in a horizontal plane. When the subject and measurer are so positioned, the subject is instructed to take a deep breath, and the measurement is made just before the subject exhales. The measurement is recorded to the nearest millimeter.

Remarks: Measurement is repeated three times. The subject has to step off after the first measurement, and take position again in between measurements. It is important that the recorder observe both the position of the subject to avoid slouching and also the position of the anthropometer to ensure that it is positioned onto the specified landmark.

20- ELBOW FINGERTIP LENGTH

Landmarks

Position

Olecranon
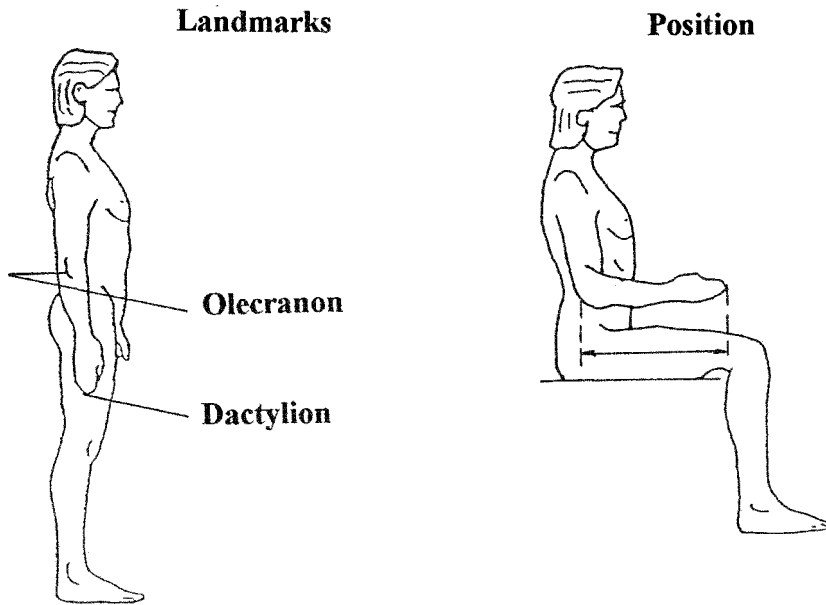
Dactylion

Definition: The distance from the tip of the elbow to the tip of the longest finger.

Landmarks: The tip of the distal phalange of the middle finger, (dactylion), and the most posterior point of the olecranon.

Instruments: Caliper or anthropometer configured as sliding beam caliper.

Position of subject: The subject sits on the table with the legs hanging unsupported over the edge of the table. The knees are directed straight ahead. The backs of the knees are near the edge of the table but not in contact with it. The subject sits as erect as possible, with the path of vision parallel to the plane of the floor. The subject's arms are vertical,

with the elbows resting lightly against the sides of the body. The elbows are flexed to about 90 degrees so that the forearms and the supinated hands are extended forwards horizontally. The fingers are together and extended in the direction of the longitudinal axes of the forearms. Subject remains in this position while the measurement is taken.

Position of measurer: The measurer stands at the subject's right side.

Procedure: The fixed arm of the beam caliper is placed to make firm contact with the most posterior surface overlying the elbow (olecranon), while the sliding arm of the caliper is shifted to make contact with the fleshy tip of the middle finger (dactylion) of the extended hand. During this measurement, the arms of sliding caliper are perpendicular to the longitudinal axis of the forearm. The measurement is recorded to the nearest millimeter.

Remarks: Measurement is repeated three times. The subject has to step off after the first measurement, and take position again in between measurements. It is important that the recorder observe both the position of the subject to avoid slouching and also the position of the caliper to ensure that it is positioned onto the right landmark.

3- Anatomical and Anthropometric Terminology Glossary.

A

Acromion: The most lateral point of the lateral edge of the spine of the scapula.

Anterior : Pertaining to the front of the body; as opposed to posterior.

B

Bust point: The most anterior protrusion of the right bra pocket.

Buttock or gluteal region: The prominence on each side formed by the gluteal muscles.

Buttock protrusion: The maximum posterior protrusion of the right buttock.

C

Canthus: A corner or angle formed by the meeting of the eyelids.

Chest: The anterior surface of the torax, overlying the pectoral muscles.

Coronal plane: Any vertical plane at right angles to the midsagital plane.

D

Dactylion: The tip of the middle finger.

Distal: The end of a body segment farthest from the head, as opposed to proximal.

E

Endocanthus: The inside corner or angle formed by the meeting of the eyelids.

External: Away from the central long axis of the body; the outer portion of a body segment.

F

Femur: The thigh bone.

H

Hip: The region between the iliac crest and the greater troahanter of the femur.

I

Iliac crest: The superior rim of the pelvic bone.

Inferior: Below, in relation to another structure; lower.

Internal: Near the central long axis of the body; the inner portion of a body segment.

L

Lateral: Lying near or toward the sides of the body; as opposed to medial.

M

Midsagittal plane: The vertical plane which divides the body into right and left halves.

O

Olecranon: The proximal end of the ulna.

P

Parietal: Convex bones, that form part of the walls of the calvaria.

Patella: The kneecap.

Phalanges: The bones of the fingers and toes.

Plantar: Pertaining to the sole of the foot.

Posterior: Pertaining to the back of the body; as opposed to anterior.

Proximal: The end of a body segment nearest the head; as opposed to distal.

R

Radiale: The upper most point on the lateral margin of the proximal end of the radius.

Radius: The bone of the forearm on the thumb side of the arm.

S

Sagital: Pertaining to the anteroposterior median plane of the body, or to a plane parallel to the median.

Scapula: The shoulder blade.

Stylion: The most distal point on the styloid process of the radius.

Superior: Above, in relation to another structure; higher.

U

Ulna: One of the bones of the forearm on the little finger side of the arm.
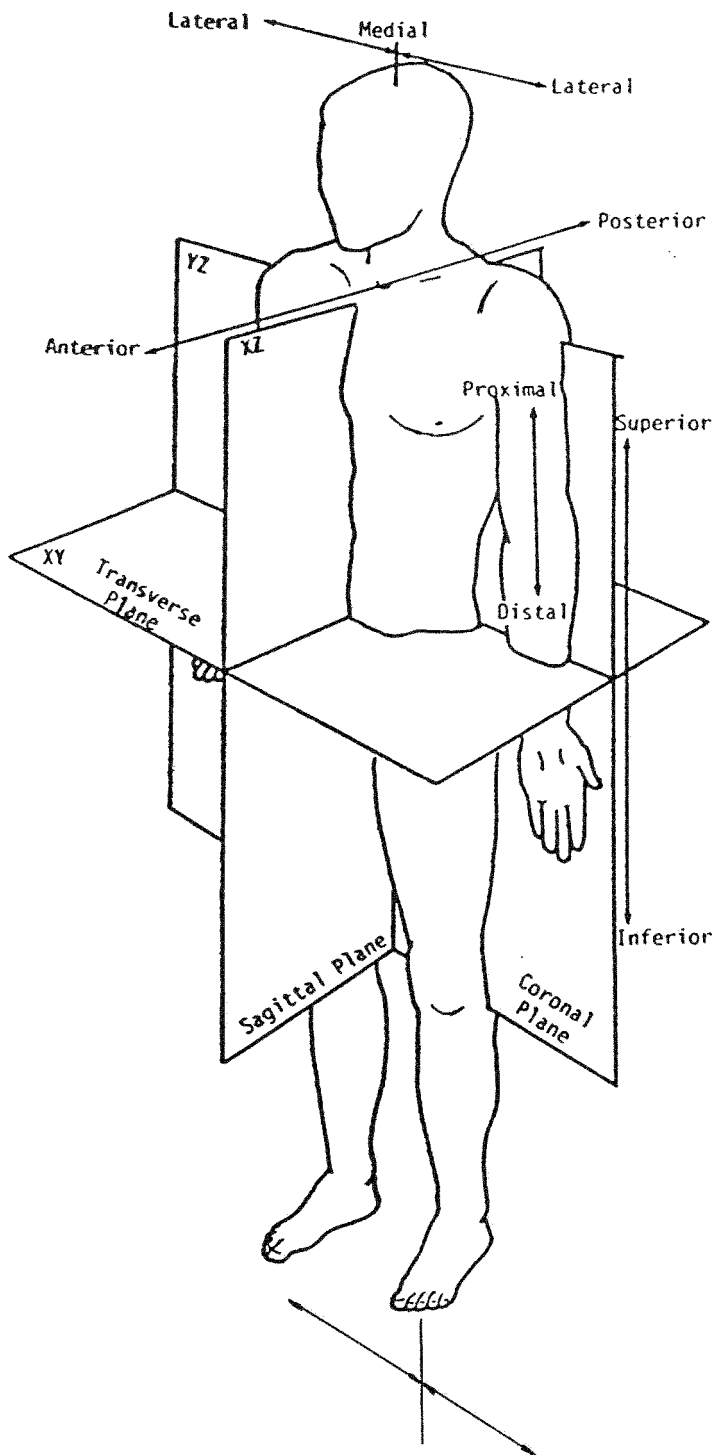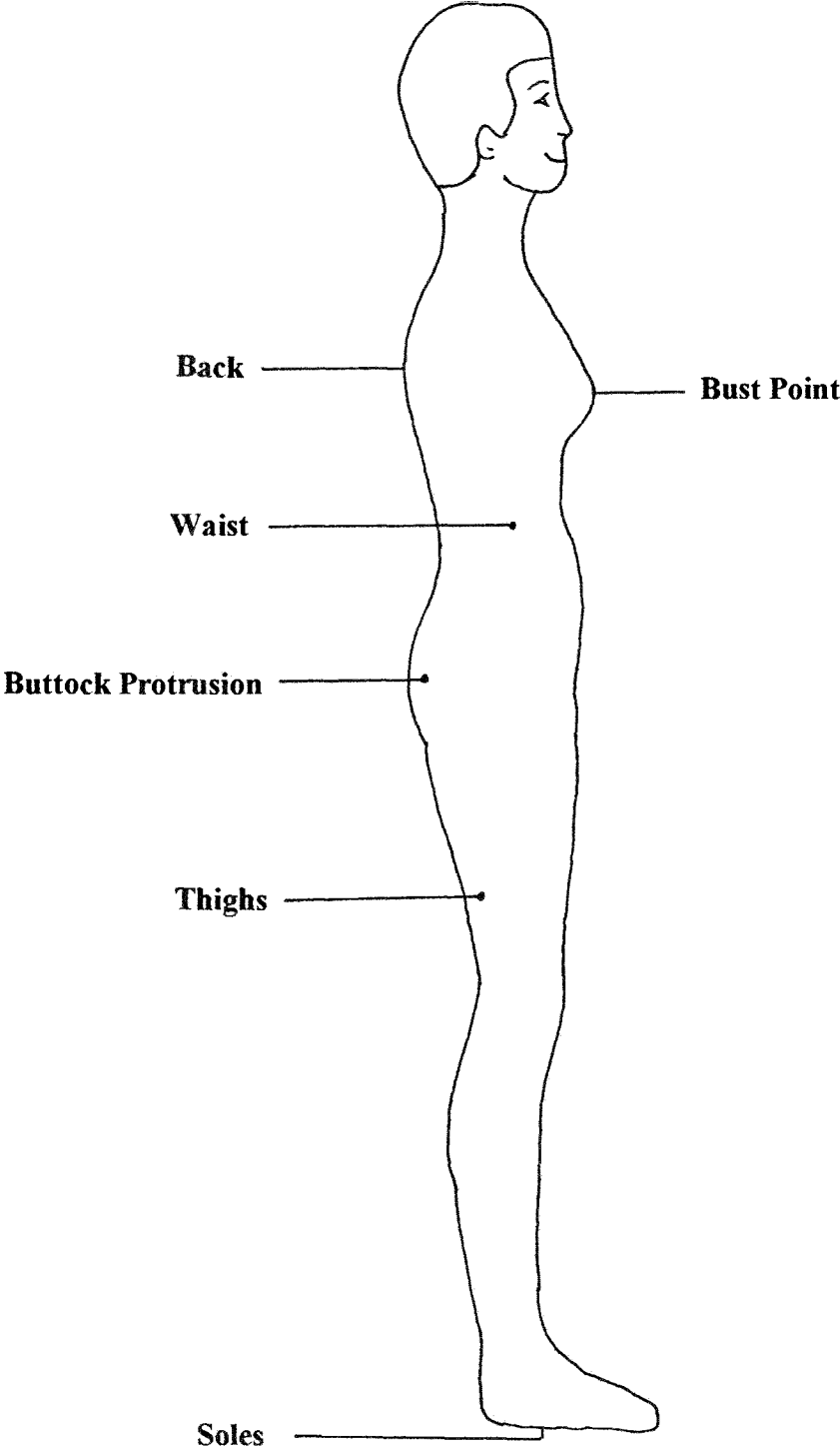
V

Vertex: The top of the head.

W

Waist: Part of the body between the ribs and the hips.

Anatomical Planes and Orientations.

Anatomical Points.

Back

Bust Point

Waist

Buttock Protrusion

Thighs

Soles

123

Anatomical Points.

Vertex

Parietal

Canthus

Acromion

Olecranon

Hip

Radial

Dactylion

Patella
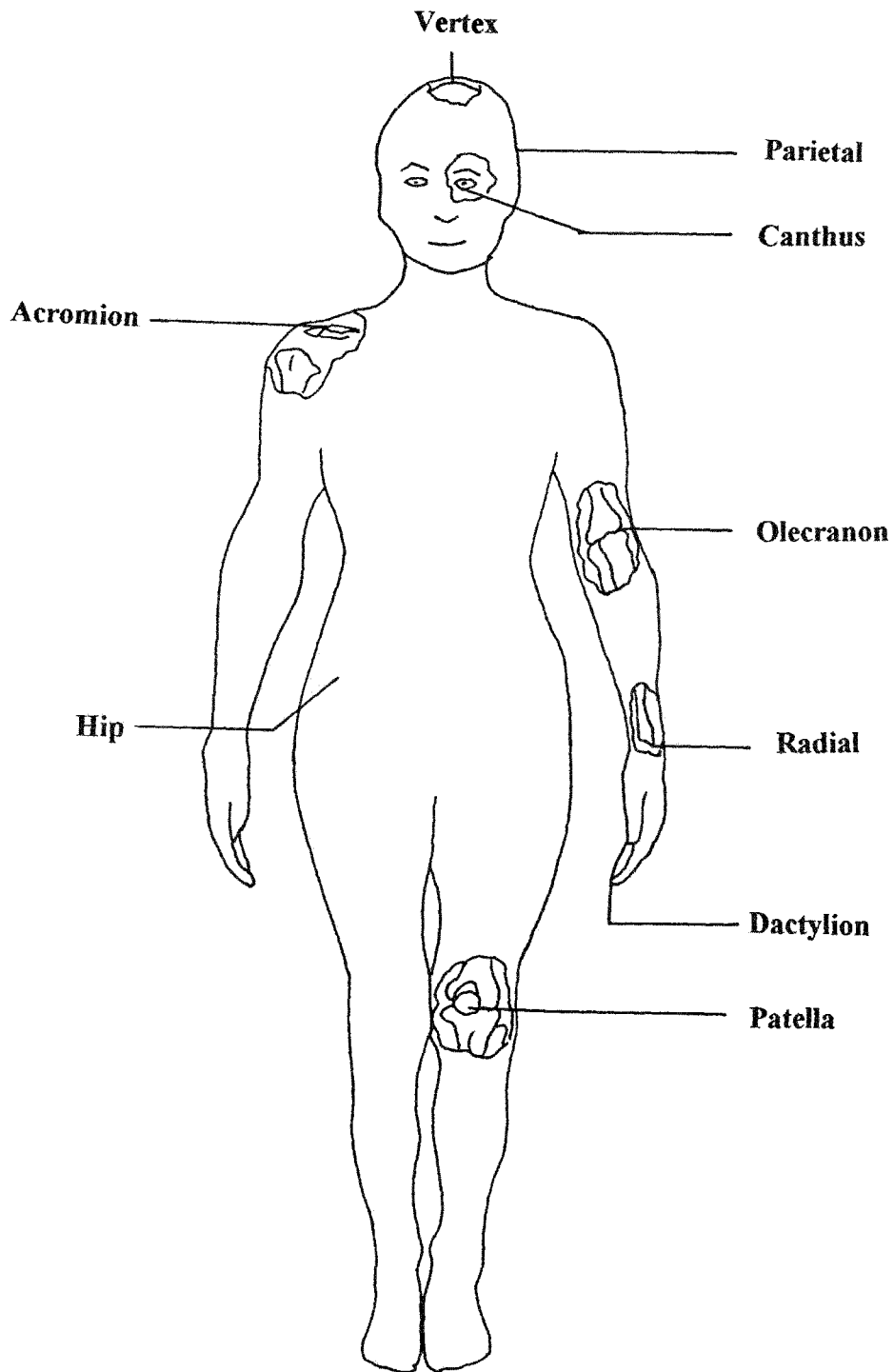
Appendix B

Sample Size Calculation

For any confidence limit:

$$d = (K) * [SD / (N)^{1/2}].$$

or

$$(N)^{1/2} = (K * SD) / d.$$

or

$$N = [(K * SD) / d]^{2}.$$

Using stature as a reference dimension and with its distribution normally distributed:

$$N = [(1.96 * 59) / 10]^{2}.$$

$$N \pm 134$$

where:

N = Sample size required.

SD = Stature standard deviation (59 mm), from the pilot study conducted in this study.

d = The desired accuracy of the measurement (10 mm), from the measurement reliability

tests conducted in this study. How close we wish our estimate to be to the true value of

the population parameter,

K= Statistical value on the standard normal distribution for the 95% confidence limit

(1.96).

Appendix C

Subject Information Form

SUBJECT INFORMATION

DATE: _____ - _____ - _____   DATE OF BIRTH: _____ - _____ - _____   AGE: _____   SEX: M F
        (month-day-year)   (month-day-year)

NAME: _____
           (last name)   (name)

PLACE OF BIRTH: _____
           (city)   (state)

OCCUPATION: _____

SUBJECT DATA

	Dimension	#1	#2	#3	X
1	Stature				
2	Eye height				
3	Shoulder height				
4	Waist height				
5	Dactylion height				
6	Elbow height				
7	Hip breadth				
8	Wrist height				
9	Upper limb length				
10	Span				
11	Vertical grip reach				
12	Sitting height				
13	Sitting eye height				
14	Sitting shoulder height				
15	Buttock knee length				
16	Knee height				
17	Shoulder breadth				
18	Head breadth				
19	Chest depth				
20	Elbow fingertip length				

MEASURER: _____