भारतीय मानक

Indian Standard

IS 17030 (Part 1) : 2024
ISO 20685-1 : 2018

अंतर्राष्ट्रीय स्तर पर संगत एंथ्रोपोमेट्रिक डेटाबेस के लिए 3-डी स्कैनिंग कार्यप्रणाली

भाग 1 3-डी बॉडी स्कैन से निकाले गए शरीर के आयामों के लिए मूल्यांकन प्रोटोकॉल

(पहला पुनरीक्षण)

3-D Scanning Methodologies for Internationally Compatible Anthropometric Databases

Part 1 Evaluation Protocol for Body Dimensions Extracted from 3-D Body Scans

(First Revision)

ICS 13.180

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NATIONAL FOREWORD

This Indian Standard (Part 1) (First Revision) which is identical to ISO 20685-1 : 2018 ''3-D scanning methodologies for internationally compatible anthropometric databases — Part 1: Evaluation protocol for body dimensions extracted from 3-D body scans' issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on recommendation of the Ergonomics Sectional Committee and approval of the Production and General Engineering Division Council.

This standard was first published in 2018 based on ISO 20685 : 2010 was later revised in two parts, that is, ISO 20685-1 : 2018 'Evaluation protocol for body dimensions extracted from 3-D body scans' and ISO 20685-2 : 2015 'Evaluation protocol of surface shape and repeatability of relative landmark positions'. It was decided to adopt both parts separately, as IS 17030 (Part 1) and IS 17030 (Part 2) and this standard is an adoption of ISO 20685-1:2018

This standard has been published in 2 parts. Other part in this series is:

Part 2 Evaluation protocol of surface shape and repeatability of relative landmark positions

The text of ISO standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are however not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'; and

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to the following International Standard for which Indian Standard also exists. The corresponding Indian Standard which is to be substituted in its place is given below along with its degree of equivalence for the edition indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO 7250-1 Basic human body measurements for technological design — Part 1: Body measurement definitions and landmarks	IS 13214 (Part 1) : 2020/ISO 7250-1 : 2017 Basic human body measurements for technological design: Part 1 Body measurement definitions and landmarks (*second revision*)	Identical

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard

Contents

Page

Introduction

Anthropometric measures are key to many International Standards. These measures can be gathered using a variety of instruments. An instrument with relatively new application to anthropometry is a three-dimensional (3-D) scanner. 3-D scanners generate a 3-D point cloud of the outside of the human body that can be used for a number of purposes, such as clothing and automotive design, engineering and medical applications. There are currently no standardized methods for using 3-D point clouds in the design process. As a result, many users extract one-dimensional (1-D) data from 3-D point clouds. This document concerns the application of 3-D scanners to the collection of one-dimensional anthropometric data for use in design.

There are a number of different fundamental technologies that underlie commercially available systems. These include stereophotogrammetry, ultrasound and light (laser light, white light and infrared). Further, the software that is available to process data from the scan varies in its methods. Additionally, software to extract dimensions similar to traditional dimensions varies markedly in features and capabilities.

As a result of differences in fundamental technology, hardware and software, extracted measurements from several different systems can be markedly different for the same individual.[1] Since 3-D scanning can be used to gather measurements, such as lengths and circumferences, it was important to develop an International Standard that allows users of such systems to judge whether the 3-D system is adequate for these needs.

The intent of this document is to ensure comparability of body measurements as specified in ISO 7250-1 but measured with the aid of 3-D body scanners rather than with traditional anthropometric instruments such as tape measures and callipers. It is further intended that conformance with this document will make any data extracted from scans suitable for inclusion in international databases such as those described in ISO 15535.[2]

Indian Standard

3-D SCANNING METHODOLOGIES FOR INTERNATIONALLY COMPATIBLE ANTHROPOMETRIC DATABASES

PART 1 EVALUATION PROTOCOL FOR BODY DIMENSIONS EXTRACTED FROM 3-D BODY SCANS

(First Revision)

1 Scope

This document addresses protocols for the use of 3-D surface-scanning systems in the acquisition of human body shape data and measurements defined in ISO 7250-1 that can be extracted from 3-D scans.

While mainly concerned with whole-body scanners, it is also applicable to body-segment scanners (head scanners, hand scanners, foot scanners).

It does not apply to instruments that measure the location and/or motion of individual landmarks.

The intended audience is those who use 3-D scanners to create 1-D anthropometric databases and the users of 1-D anthropometric data from 3-D scanners. Although not necessarily aimed at the designers and manufacturers of those systems, scanner designers and manufacturers can find it useful in meeting the needs of clients who build and use 1-D anthropometric databases.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 7250-1, *Basic human body measurements for technological design — Part 1: Body measurement definitions and landmarks*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7250-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

NOTE In the case of definitions of terms for skeletal landmarks, when there is a separate term for the skin overlying the landmark and another for the landmark itself, the skin landmark term is used. Where there is no separate term, the skeletal term is used and assumed to refer to the skin overlying the landmark.

3.1
three-dimensional
3-D
pertaining to the use of three orthogonal scales on which the three coordinates, *x*, *y* and *z*, can be measured to give the precise position of any relevant anatomical point in the considered space

Note 1 to entry: Many anthropometric distances can be calculated from the coordinates of *anatomical landmarks* (3.6). Some additional points may be necessary to obtain circumferences.

3.2
3-D body scanner
hardware and software system that creates digital data representing a human form, or parts thereof, in three dimensions

3.3
3-D scanner software
operating system, user interface, programs, algorithms and instructions associated with a 3-D scanning system

3.4
3-D scanner hardware
physical components of a 3-D scanner and any associated computer(s)

3.5
accuracy
extent to which the measured value approximates a true value

Note 1 to entry: Since it is difficult to trace the accuracy of complex hardware and software systems to recognized ISO sources, for the purposes of this document *true value* is taken to mean the measured value obtained by an anthropometrist with several years' experience in the methods of ISO 7250-1, using traditional instruments such as tape and calliper.

3.6
anatomical landmark
point clearly defined on the body that can be used for defining anthropometric measurements

3.7
anthropometric database
collection of individual body measurements (anthropometric data) and background information (demographic data) recorded on a group of people (the sample)

[SOURCE: ISO 15535:2012, 3.8]

3.8
lateral malleolus
most lateral point of the right lateral malleolus (outside ankle bone)

3.9
point cloud
collection of 3-D points in space referenced by their coordinate values

Note 1 to entry: A point cloud constitutes the raw data from a 3-D scanner and needs to be translated to a human *axis system* (3.13).

3.10
repeatability
extent to which the values of a variable measured twice on the same subject are the same

3.11
ulnar stylion
most distal point on the ulnar styloid, projected horizontally and posteriorly to the surface of the skin when the arms are held down and the palms are facing the thighs

3.12
vertical plane
geometric plane tangent to a point on the body and orthogonal to the mid-sagittal plane

3.13
***x*, *y*, *z* coordinate system**
axis system
system for measuring the body with respect to the standing or sitting human where X refers to the fore-and-aft direction (the sagittal axis), Y refers to the side-to-side direction (the transverse axis) and Z refers to the top-to-bottom direction (the longitudinal axis) (see Figure 1)

Note 1 to entry: Researchers establish their own origin for the axis system, convenient to their research, while keeping the direction of the axes as indicated and reporting the origin in the data base and any publications.

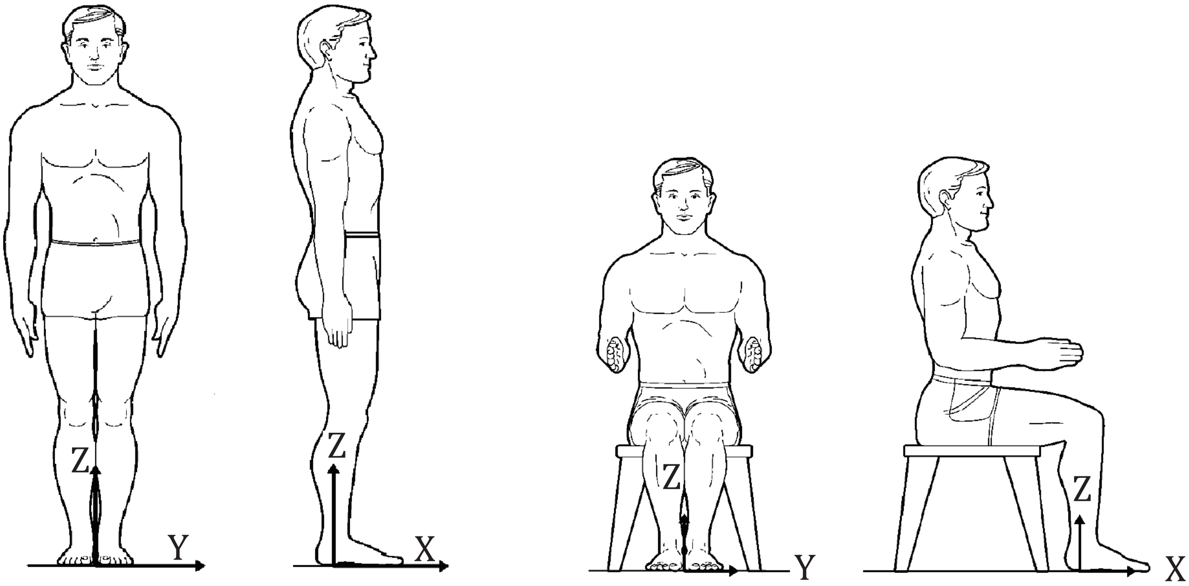


Figure 1 — *x*, *y*, *z* coordinate system

4 Accuracy of extracted measurements

4.1 Selection of extracted measurements

In order to use data from 3-D body scanners in internationally compatible databases, dimensions should be drawn from ISO 7250-1. However, not all of those measurements are well suited to extraction from 3-D scanned images. In particular, the resolution from whole-body scanners might not be sufficient to allow accurate extraction of measurements from smaller body parts such as the hand. Tables 1 to 3 give measurements according to the type of scanner most likely to produce the best results. The numbers indicate the measurement number in ISO 7250-1.

Table 1 — ISO 7250-1 measurements by whole-body scanner

Dimension	ISO 7250-1:2017	Position (see A.2.4)
Stature (body height)	6.1.2	B
Eye height	6.1.3	B
Shoulder height	6.1.4	B
Elbow height	6.1.5	C
Iliac spine height, standing	6.1.6	B
Crotch height	6.1.7	B
Tibial height	6.1.8	B
NOTE For whole-body scanners, depending on the type of scanning system used, the positions according to A.2.4 can also be useful for extracting the indicated dimensions.		

Table 1 *(continued)*

Dimension	ISO 7250-1:2017	Position (see A.2.4)
Chest depth, standing	6.1.9	A, B
Body depth, standing	6.1.10	A, B
Chest breadth, standing	6.1.11	A
Hip breadth, standing	6.1.12	A
Sitting height (erect)	6.2.1	D
Eye height, sitting	6.2.2	D
Cervicale height, sitting	6.2.3	D
Shoulder height, sitting	6.2.4	D
Elbow height, sitting	6.2.5	D
Shoulder–elbow length	6.2.6	C
Shoulder (biacromial) breadth	6.2.7	A, B
Shoulder (bideltoid) breadth	6.2.8	A, B
Elbow-to-elbow breadth	6.2.9	D
Hip breadth, sitting	6.2.10	D
Popliteal height, sitting	6.2.11	D
Thigh clearance	6.2.12	D
Knee height, sitting	6.2.13	D
Abdominal depth, sitting	6.2.14	D
Thorax depth at the nipple	6.2.15	B
Buttock–abdomen depth, sitting	6.2.16	D
Elbow-wrist length	6.4.3	C
Forearm–fingertip length	6.4.6	C
Buttock–popliteal length	6.4.7	D
Buttock–knee length	6.4.8	D
Neck circumference	6.4.9	A, B
Chest circumference	6.4.10	A
Waist circumference	6.4.11	A
Wrist circumference	6.4.12	A
Thigh circumference	6.4.13	A
Calf circumference	6.4.14	A
NOTE For whole-body scanners, depending on the type of scanning system used, the positions according to A.2.4 can also be useful for extracting the indicated dimensions.		

Table 2 — ISO 7250-1 measurements by head scanner

Dimension	ISO 7250-1:2017
Head length	6.3.9
Head breadth	6.3.10
Face length (menton-sellion)	6.3.11
Head circumference	6.3.12
Sagittal arc	6.3.13
Bitragion arc	6.3.14

Table 3 — ISO 7250-1 measurements by hand or foot scanner

Dimension	ISO 7250-1:2017
Hand length (stylion)	6.3.1
Palm length	6.3.2
Hand breadth at metacarpals	6.3.3
Index finger length	6.3.4
Index finger breadth, proximal	6.3.5
Index finger breadth, distal	6.3.6
Foot length	6.3.7
Foot breadth	6.3.8

4.2 Standard values

The human body is difficult to measure and does not lend itself to standards of accuracy that can be applied to machine tooling, for example. For the purposes of this document, the standard for accuracy of a measurement extracted from a 3-D image is the corresponding traditional measurement, when measured by an anthropometrist with several years' experience in the methods of ISO 7250-1.[4] [5] [6] The difference between an extracted measurement and the corresponding traditional measurement on actual subjects should be derived using the test methods given in Clause 5. If the values are lower than those specified in Table 4, then the measurement may be included in ISO 15535 databases.

As any good scientific report documents the observer and measurer error, the accuracy of extracted measurements should be reported in any documentation that results from the use of these systems.

Table 4 — Maximum allowable error between extracted value and traditionally measured value

Measurement type	Maximum mean difference (see 5.4) mm
Segment lengths (e.g. buttock-popliteal length)	5
Body heights (e.g. shoulder height)	4
Large circumferences (e.g. chest circumference)	9
Small circumferences (e.g. neck circumference)	4
Body breadths (e.g. biacromial breadth)	4
Body depths (e.g. chest depth)	5
Head dimensions without hair	1
Head dimensions with hair	2
Hand dimensions	1
Foot dimensions	2

5 Research design for a validation study to establish accuracy of body dimensions extracted from scanners

5.1 General

The purpose of this document is to ensure that body measurements obtained from 3-D systems are sufficiently close to those produced by ISO 7250-1 traditional methods that they can be substituted for one another without compromising the validity of standards relying on the data. Annex A contains information that is helpful in meeting this goal. In order to demonstrate that a 3-D system is in conformance with this document, a validation study shall be conducted.

5.2 Validation study procedures

All ISO 7250-1 variables that are to be measured by 3-D methods shall be included in the validation study.

The 3-D scanning and data extraction system used for the validation shall be exactly the same hardware and software configuration that is used in collecting the ISO 7250-1 data for inclusion in an ISO 15535 database.

The traditional measurer shall be an expert, trained and experienced in ISO 7250-1 techniques. He or she shall have recently practiced the ISO 7250-1 protocols for the body measurements in the study. It is preferable that the same expert measure all test subjects. If landmarks are to be marked prior to scanning, the positioning of landmarks should be done by an expert trained and experienced in ISO 7250-1 techniques.

Each subject shall be scanned and measured traditionally at least once. The order of scan and measuring shall be counterbalanced to control for measurement order effects; however they shall occur sequentially on the same day in order to minimize error introduced by transient intra-individual fluctuations in body dimensions (see Annex A).

5.3 Sampling size and test subject selection

A power analysis such as that presented in Clause 6 shall be done in order to ensure that the validation study sample size is large enough to detect mean scan-measure differences of the magnitudes presented in Table 4 with 95 % confidence. A sample of at least 40 test subjects is recommended, since this ensures 95 % confidence in the validation test results for large circumferences such as chest, waist, and hip, which are particularly difficult to measure for both traditional and 3-D measurement systems.

Validation test subjects shall reflect approximately the same range of body sizes and shape variations expected in the study population that is to be measured by the 3-D system. If both males and females are to be measured, then the validation sample shall include an equal number of each sex. The validation sample shall also include a variety of body types — not just people of average height and weight. If children are to be measured, it is particularly important that the validation sample cover the age range of the intended survey population.

5.4 Analytical procedures

After data collection is complete, the difference, δ, between the scan-extracted value and the measured value (δ = scan minus measure) shall be computed for each variable and test subject, and the mean of these differences shall be calculated for each variable and reported with its associated standard deviation, sample size and 95 % confidence interval. If the 95 % confidence interval for the mean of scan-minus-measure differences is within the plus or minus interval defined by the values in Table 4, then the 3-D system can be said to give results sufficiently comparable to ISO 7250-1 methods such that the 3-D data may be used in standards relying on ISO 7250-1 protocols. The values in Table 4 come from research conducted by the U.S. Army[5].

Table 5 shows how the analysis of test data should be done, and how the correct conclusion can be reached. The difference between the scan-extracted value and the measured value should be calculated for each subject. Then, the mean and standard deviation of those differences should be calculated. Next, the 95 % confidence interval should be calculated. The confidence interval is a function of the mean, the standard deviation, the desired level of confidence (as a Z score) and the sample size. In the case of the 95 % confidence interval, the lower and upper limits can be calculated with Formulae (1) and (2):

$$\bar{x} - \left(s \cdot \frac{1{,}96}{\sqrt{N}} \right) \quad (1)$$

$$\bar{x} + \left(s \cdot \frac{1{,}96}{\sqrt{N}} \right) \quad (2)$$

where

$\bar{x}$ is the mean;

s is the standard deviation;

N is the number of subjects.

Next, the comparison value is selected from Table 4, according to the type of dimension. In Table 5, we use 4 mm for Stature, since it is a body height (the second row of Table 4). In the example, both upper and lower 95 % confidence limits are less than 4, so the conclusion would be that the scan-extracted value would be close enough to the measured value that it can be included in ISO databases.

The second dimension, hand length, has a different result. Following the same calculations, the lower 95 % confidence limit is less than 1, the comparison value from Table 4 (second to last row), but the upper limit is greater than 1. In this case, the scan-extracted data for hand length should not be included in ISO databases.

Table 5 — Example showing test data, calculations and conclusion

	Stature			Hand length		
Subject	**Scan-extracted value**	**Measured value**	**Difference**	**Scan-extracted value**	**Measured value**	**Difference**
1	1 925	1 920	5	123	121	2
2	1 872	1 880	−8	150	158	−8
3	1 660	1 670	−10	160	158	2
4						
.						
.						
.						
.						
40	1 880	1 886	−6	145	148	−3
N			40			40
Mean			2,8			1,4
SD			3,8			2,9
Lower limit			1,622			0,501
Upper limit			3,978			2,299
Max. allowable error			4			1
Evaluation result			Acceptable			Unacceptable

5.5 Validation study reporting

A report of the validation study shall be published and/or included in the anthropometric survey report associated with any 3-D database provided for use in standards relying on ISO 7250-1 protocols. This report shall include the following information:

— demography (age, sex) and anthropometry (height, weight) of the test subjects;

— protocols for measuring and scanning, including subject clothing, anthropometric landmarks, and body positions;

— name and pertinent details (or references) describing the 3-D system being validated, including hardware model number, and software version number;

— means, standard deviations, sample sizes for each body dimension as measured by scanning and as measured traditionally;

— means, standard deviations, sample sizes and 95 % confidence intervals for scan-minus-measure differences for each body dimension.

6 Method for estimating the number of subjects needed

In order for scanner–measurer comparisons to be statistically valid, it is important that test samples be large enough to detect mean differences of the magnitude specified in Table 4 at least 95 % of the time, at the level of 0,05 or better.

Assuming that the differences observed between extracted values and measured values are normally distributed, the minimum sample size required for a one-sample test of differences, n, can be estimated using Formula (3)[7]:

$$n = \frac{s^2}{\delta^2} \times (1{,}96 + 1{,}65)^2 \quad (3)$$

where

s is the standard deviation of extracted-minus-measured differences;

δ is the magnitude of the extracted-minus-measured difference that must be detected;

1,96 is the critical Z value for a two-sided 0,05 level test;

1,65 is the critical Z value for 95 % confidence.

In practice, the true standard deviation of extracted-minus-measured differences for a particular system is usually unknown, so it is estimated from previous studies of similar systems. A pilot study can be necessary. The magnitude of difference to be detected, δ, is obtained from Table 4, and varies among different classes of body dimensions.

Because the variance of extracted-minus-measured differences is different for each body dimension, and because the magnitude of extracted-minus-measured differences to be detected also varies among dimension classes, the investigator usually makes several sample-size estimates for different body dimensions, and chooses the largest result to establish the minimum sample size required. When this approach is taken, the calculated sample size is sufficient for 95 % confidence in 0,05 level tests in the worst case, and it is more than sufficient for all the other body dimensions.

EXAMPLE Suppose an investigator wishes to establish the validity of using scan-extracted circumferences in place of directly measured circumferences. Previous studies resulted in extracted-minus-measured differences with standard deviations as follows: chest circumference 16 mm, waist circumference 14 mm and buttock circumference 12 mm, see Bibliographic references[2] and.[5] Using Formula (3) and a required detectable difference of 9 mm for large circumferences reported as a mean difference (see Table 4), the investigator determines that 42 subjects are required to test chest circumference, 32 subjects are required for waist circumference, and 24 subjects are required for buttock circumference. Using 42 subjects ensures 95 % confidence or better for all three circumferences to be tested.

Annex A
(informative)

Methods for reducing error in 3-D scanning

A.1 General

There are a number of sources of anthropometric error (here, the difference between a scanner-extracted measurement and a measurement obtained by an anthropometrist with several years' experience in the methods of ISO 7250-1). This annex outlines the main sources of error, and methods for documenting and reducing it.

A.2 Subjects

A.2.1 General

The best anthropometric data is available from scans whose subjects have been properly prepared in advance of the scanning. This preparation includes marking some anatomical landmarks, selection of appropriate scanning attire, and positioning the subject in the scanning volume.

A.2.2 Anatomical landmarks

Landmarks should be marked on the skin, and then identified with dots or other techniques that can be seen on the displayed image, and distinguished using the available software. Bilateral landmarks should be marked on both sides of the body. If landmarks (see Clause 3) are to be marked before scanning, a minimal list would be the following:

a) acromion;

b) cervicale;

c) crotch level;

d) glabella;

e) iliocristale;

f) iliospinale anterius;

g) orbitale (infraorbitale);

h) lateral malleolus;

i) lowest point of rib cage;

j) menton;

k) mesosternale;

l) opisthocranion;

m) sellion;

n) stylion (radial stylion);

o) suprapatella, sitting;

p) thelion;

q) tibiale;

r) tragion;

s) ulnar stylion;

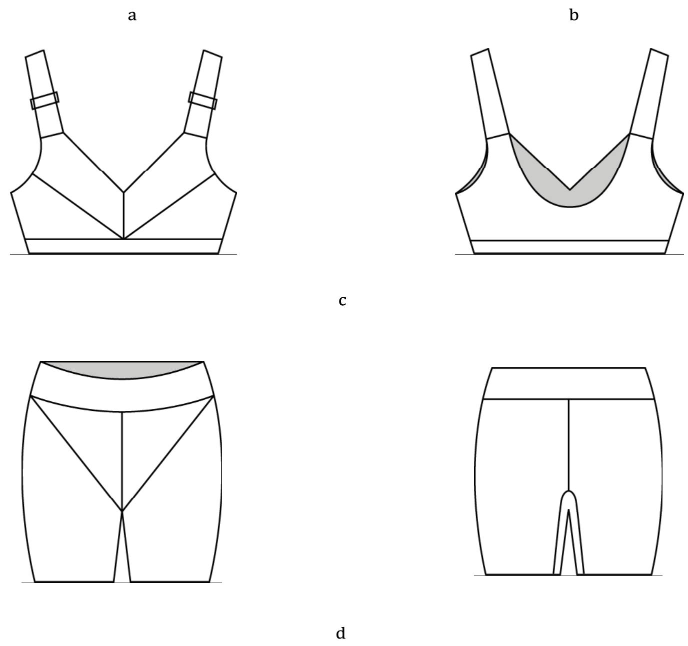
t) vertex (top of head).

A.2.3 Scanning attire

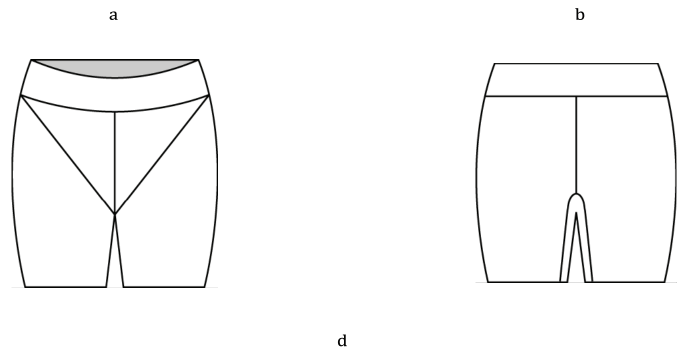
The scanning attire should be minimal, within the bounds of modesty (recognizing cultural differences). It should be form-fitting, so that there is no bagginess or folds. At the same time, however, it should not compress the flesh. The texture and colour should be such that it is seen on the scanned image. Testing with each particular scanning system is required to demonstrate the appropriateness of the fabric. The upper garment (women) should be constructed so the mesosternale point is clearly visible. The shoulder straps should not interfere with measurement points. The lower garment should expose the navel, and the inseam length should not interfere with measurement points of lower limbs. The pattern should be one that results in no side seam on the thigh.

A sample garment is shown in Figure A.1. Men need only wear the lower garment.

Surface scanners can capture the contour of the hair, rather than the head itself. Therefore, if measurements involving the head are contemplated, suitable arrangements should be made in respect of the hair so that accurate data on the head, neck and shoulder can be obtained. The use of flexible caps with holes in the centre is suggested for subjects with long or irregular hair styles (see Figure A.2). Alternatively, software in the scanning system may address the issue of hair contours in other ways.



a) Women



b) Men

Key

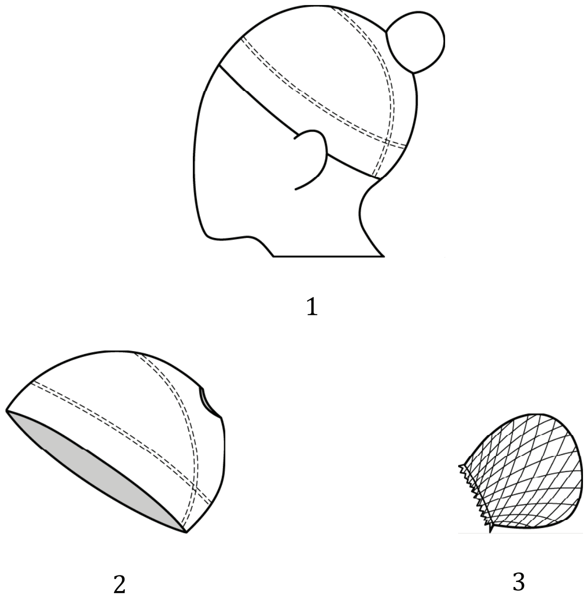
a Front.

b Back.

c Upper.

d Lower.

Figure A.1 — Sample garments for scanning



Key

1 with cap

2 cap

3 hair net

Figure A.2 — Suggested means for managing hair

A.2.4 Subject position

The position of the subject in the scanning volume is important for obtaining reliable data that can be used in an anthropometric database. However, because scanning systems vary, the optimal position can vary from system to system. When the optimal position is determined, it should be described precisely and used for all subjects. It is also important that the subject hold the posture during the entire scanning process. Depending on the optimal position(s), one or more support devices can be used. It should be noted that the scanning postures used can differ from those specified in ISO 7250-1, because ISO 7250-1 postures present difficulties for many scanning systems, for example, the masking of some body parts by other body parts. As a result, some corrections need to be made for certain measurements in order to meet the accuracy standards according to Clause 6. Corrections can be made by using multiple scan postures, or by mathematical transformations after the scan is complete. Examples of mathematical transformations include a regression prediction based on laboratory experimentation, and a geometric transformation based on the height of the hip and distance between the feet.

For all postures, quiet respiration (normal breathing) should be adopted. The shoulders should be straight without being stiff, and muscles should not be tense. Some postures are described below, illustrated in Figure A.3.

— **Standing position A**

  The head is in the Frankfurt plane; the long axes of the feet should be parallel to one another and 200 mm apart; the upper arms are abducted to form a 20° angle with the sides of the torso, and the elbows are straight; the palms face backward, and the subject is breathing quietly. This position can be used for obtaining circumferences of the upper and lower limbs.

— **Standing position B**

  The subject stands erect with the head in the Frankfurt plane. The heels are together, the upper limbs hang relaxed at the side, palms facing the body. The abdomen is relaxed and the subject is breathing quietly. To identify the crotch, a horizontal straightedge is placed between the lower limbs so that the uppermost edge is at the level of the crotch. (The straightedge is placed with the feet apart, and adjusted upwards after the heels are moved together.) This position can be used for obtaining heights from the floor.

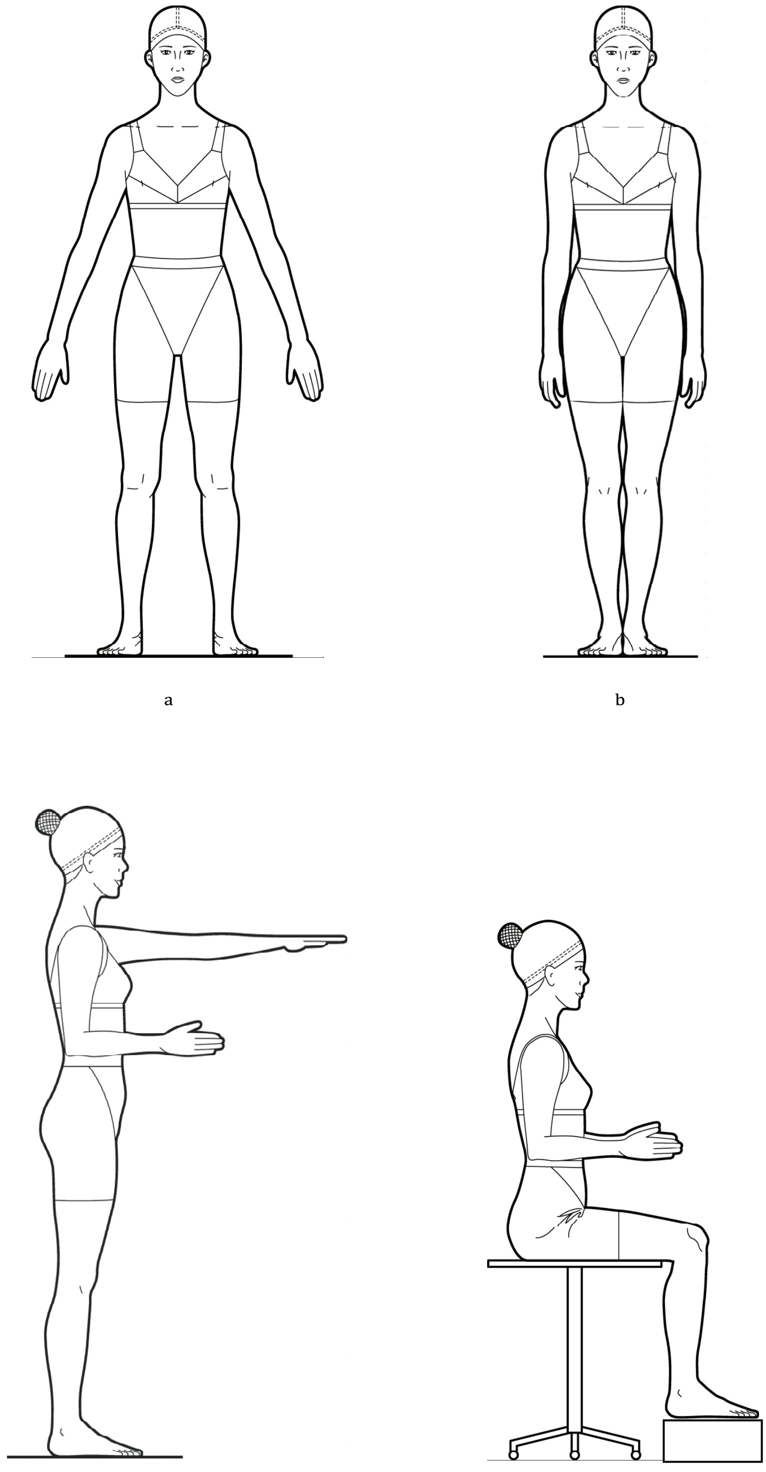
— **Standing position C**

The subject stands as for position B, but with one upper limb stretched forward horizontally and the palm facing inferiorly, while the other is bent 90° at the elbow with the palm facing medially.

— **Sitting position D**

The subject sits erect with the head in the Frankfurt plane; the upper limbs hang down at the side, but the arms are bent 90° at the elbow, and the palms are flat, facing one another. The thighs are parallel to each other, and there is a 90° angle between the thigh and torso. The feet are supported so that the femora are horizontal and parallel to each other.

NOTE The act of sitting on the platform compresses body tissues, so that standing and sitting segments are not comparable.



a b c d

Key

a Standing position A.

b Standing position B.

c Standing position C.

d Sitting position D.

Figure A.3 — Standing and sitting positions[9][10]

A.3 Hardware

A.3.1 General

The capabilities of 3-D scanner hardware are distinct from those of 3-D scanner software. While the hardware and software are often bundled together for sale as a single system, they are treated separately here. For both, the default unit of measurement is millimetres. The recommendations in this clause for testing hardware are explained in more detail in ISO 20685-2[8].

A.3.2 Resolution

The distance between points in scan data (resolution) should be defined separately for each of the three axes. Users should be aware that resolution can vary within the scanning volume and with the curvatures of the object being scanned. These variations in resolution, along with the size of the subject and the placement and curvature of body parts within the scanning volume, can affect the accuracy of certain measurements.

A.3.3 Test and calibration

A.3.3.1 Calibration

The scanner hardware should be calibrated when first delivered, and should be recalibrated periodically. The frequency of calibration should be related to the type of scanner and the frequency of use. Calibration should always be verified after moving the scanner.

Users should follow the calibration procedure recommended by the manufacturer before testing the hardware with the procedures given below.

A.3.3.2 Test object

The hardware should be tested with an object of known dimensions. While many different objects can be used, it is helpful to use an object some of whose dimensions are similar to those found in humans. The test object can be useful in verifying the scanning volume.

As the test procedures recommended below involve placing the test object at various points within the scanning volume, it is helpful to have a test rig that can place the object precisely and reliably.

A.3.3.3 Test measurements

The following test measurements should be made on the test object:

— point-to-point distance;

— arc length;

— cross-section circumference.

A.3.3.4 Accuracy

Usually, it is not possible for the user to test machine accuracy. However, using a commercially available CAD package (not the scanner manufacturer’s software) to verify the dimensions of the point cloud of the test object helps to identify serious error. The dimensions of the test object should be obtained using calibrated traditional instruments, such as callipers or tape.

a) Place the test object in the centre of the scanning volume on the floor or a platform.

b) Use the manufacturer's software to record the locations of all marked points.

c) Repeat the procedure at 500 mm, 1 000 mm, 1 500 mm and 2 000 mm off the floor/platform, above the first location.

d) Use the manufacturer's software to record the physical locations of all the marked points at each level.

e) Repeat the procedure at other locations near the edge of the scanning volume, as appropriate.

A.3.3.5 Repeatability

The locations of the points on the test object should be recorded from at least three scans, to assure repeatability of the hardware. This does not need to be done at each of the locations indicated in A.3.3.4, but should be done at least in the centre of the scanning volume.

A.3.3.6 Statistics

With only three replications, the analysis of the hardware repeatability data can be limited to an examination of the minima, the maxima and mean differences.

A.3.3.7 Multiple cameras

The camera should be tested to determine if it is operating, and to determine its field of view. If there are multiple cameras, the output of each camera should be tested individually, before the images are registered.

A.3.4 Scanning volume

The scanning volume should be large enough to accommodate considerable human variability. A volume of at least 2 100 mm in height (Z axis) and a width of 1 200 mm (Y axis) and depth of 1 000 mm (X axis) is recommended.

A.3.5 Scanning duration

To minimize movement artefacts, the scanning process should not take longer than 20 s.

A.3.6 Additional sources of error

Additional sources of error in hardware include colour perception, luminance perception and the shadowing of body parts by other body parts. Users need to be aware that these sources of error can affect extracted measurements.

A.4 Software

A.4.1 General

Early versions of scanning systems included various software tools bundled with the software required for operating the scanner. Nowadays, software is available from a number of developers and is not necessarily tied to any one scanner.

In order to successfully use 3-D scanning for anthropometric databases, it is useful to have certain software features available. Software can allow the user to manipulate the figure, identify various body landmarks and segment the body into its component parts. Finally, software can extract measurements that can be similar to those measured with traditional anthropometric instruments.

A.4.2 Features for human-figure manipulation

A.4.2.1 Zoom

The software can allow the user to move the figure closer — enough so that a single point can be identified — and farther away, so that the whole scanned image is visible.

A.4.2.2 Pan or translate

The software can allow the user to move the figure along each axis, throughout the scanning volume.

A.4.2.3 Rotate

The software can allow the user to rotate the human figure 360° in each axis.

A.4.2.4 Floating axis

At the user's option, the software can allow the XYZ axis indicator, as well as the origin of the axis system, to remain visible continuously.

A.4.3 Features of landmark identification

A.4.3.1 The software should allow landmarks to be identified either manually or automatically, and to be recognized as individual variables, with names or numbers.

A.4.3.2 The software should allow the user to assign names or numbers to identified landmarks, and allow the input or output of lists of landmark names, in ASCII code, according to ISO/IEC 8859-1[3].

A.4.3.3 The software should allow the user to create a file containing landmark names and their 3-D coordinates.

The file format should be:

text, tab delimited (in ASCII code, according to ISO/IEC 8859-1).

The structure of the file should be:

X [tab] Y [tab] Z [tab] Landmark Name [return].

A.4.3.4 The software should allow the user to visualize landmarks (with colour, or differential brightness) on the screen, with or without the figure. This feature should be available for all landmarks or a subset of landmarks.

A.4.4 Features of segmentation

A.4.4.1 The software can give the user the ability to separate body parts (upper limbs, lower limbs, torso, etc.) from the rest of the body — either automatically, using identified landmarks, or manually, using the cursor. If automatic segmentation is used, the user should verify that the segmentation points are appropriate for his or her purposes.

A.4.4.2 The software can give the user the ability to visualize one or more segments independent of the whole image.

A.4.4.3 The software can allow the user to pan, rotate and zoom segments.

A.4.4.4 The software can allow the user to pan, rotate and zoom the viewing field.

A.4.5 Features of measurement extraction

A.4.5.1 Manual measurements

From an identified point, the software should give the user the ability to:

— extract the height from floor/platform;

— extract the distance from the vertical plane at the most posterior point on the body;

— extract the distance from the vertical plane at the most anterior point on the body;

— extract the distance from the vertical planes at the right or left most points on the body;

— calculate the horizontal or vertical circumference from an identified point; and

— calculate the circumference along a user-identified plane.

From two identified points, the software should give the user the ability to:

— calculate the point-to-point distance in 3-D space between the points;

— calculate the vertical distance between the points;

— calculate the horizontal distance between the points;

— calculate the shortest surface distance between the points; and

— create and measure a cross-section for measuring along the surface, and as an outer hull.

A.4.5.2 Automatic measurements

The software can give the user the ability to define a measurement in terms of landmarks and procedures (e.g. a horizontal circumference or a point-to-point distance), and then extract that dimension automatically.

A.4.6 Data storage

Data should be stored in the raw format native to the system. The single exception is the case of a multiple-image system, where the images should be aligned and merged before storing. If the data are compacted before storage, the polygon reduction information should be retained. Outlying points should be eliminated before storage.

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