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3-D scanning methodologies for internationally compatible anthropometric databases —

Part 1: Evaluation protocol for body dimensions extracted from 3-D body scans

Méthodologies d'exploration tridimensionnelles pour les bases de données anthropométriques compatibles au plan international —

Partie 1: Protocole d'évaluation des dimensions corporelles obtenues à l'aide de scanners 3D

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 3, *Anthropometry and biomechanics*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

This first edition cancels and replaces ISO 20685:2010.

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]

3-D scanning methodologies for internationally compatible anthropometric databases —

Part 1: Evaluation protocol for body dimensions extracted from 3-D body scans

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.

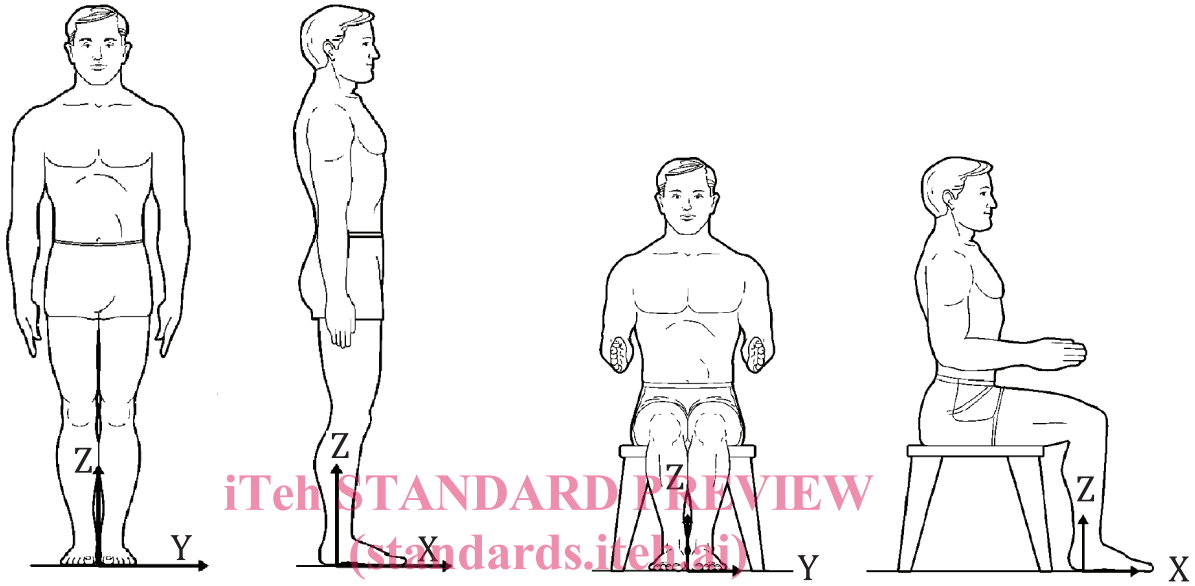

Figure 1 — *x*, *y*, *z* coordinate system

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.