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Ergonomics — Computer manikins and body templates —

Part 2:
Verification of functions and validation of dimensions for computer manikin systems

Ergonomie — Mannequins informatisés et gabarits humains —

Partie 2: Vérification des fonctions et validation des dimensions pour les systèmes de mannequins informatisés

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Contents

Page

Foreword iv
Introduction v
1 Scope 1
2 Normative references 1
3 Terms and definitions 2
4 Requirements for computer manikin verification 3
4.1 General 3
4.2 Listing of functions 3
4.3 Description of functions 3
4.4 Verification of functions — Examples supplied by developers 3
4.5 Verification of functions — Enabling manikin system user to record/report performance 3
5 Requirements for documenting source data 3
5.1 Listing of parameters 3
5.2 Parameter description 3
5.3 Sampling method 4
5.4 Sample demographics 4
6 Requirements for computer manikin validation 4
6.1 General requirements 4
6.2 Static functions 5
6.3 Reporting test results 6
Annex A (informative) Recommended nomenclature and definitions of joint movements for modelling humans 7
Annex B (informative) Static-test protocol 16
Bibliography 17

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15536-2 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 3, *Anthropometry and biomechanics*.

ISO 15536-2 was prepared by the European Committee for Standardization (CEN) Technical Committee CEN/TC 122, *Ergonomics*, in collaboration with Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 3, *Anthropometry and biomechanics*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

ISO 15536 consists of the following parts, under the general title *Ergonomics — Computer manikins and body templates*:

— *Part 1: General requirements*

— *Part 2: Verification of functions and validation of dimensions for computer manikin systems*

Introduction

In order to apply computer manikins with confidence and trust to equipment design, designers need to know the accuracy and reliability of these tools. The needed accuracy depends on the purpose of their use. Some designers need high degrees of accuracy (e.g. quantitative clearance analyses), while others need less (e.g. training simulations). A method of checking the basic degree of accuracy is given in ISO 15536-1:2005. It is based on the comparison between anthropometric data used in creation of the manikin and the corresponding measurements taken from the manikin itself. These data and measurements apply to the standardized measurement postures only, i.e. standing and sitting (see ISO 7250:1996).

However, computer manikins are used to simulate a wider range of human postures and movements during equipment design than standardized postures, and it is essential that designers know the level of their anthropometric accuracy also in these conditions. Moreover, problems arise when trying to assess the accuracy and repeatability of computer manikins and their associated applications because of the many anthropometric and biomechanical parameters used in constructing them. Many specialized tests are required to accurately measure every possible size, shape and working posture that people can exhibit. This problem is further compounded when manikin data or algorithms are changed, requiring additional tests assessing their dimensional accuracy.

Because it is not economically feasible for one organization to test every manikin parameter under every possible test condition, developers and users need to share the responsibility for assessing computer manikin accuracy. Developers may test manikin system accuracy for the most common situations, but it is essential that the users be provided with the means to test the accuracy and repeatability of manikin systems for their specific applications, too. Therefore, users need to measure manikin accuracy for their specific applications and developers need to provide computer manikins and simple processes for measuring and assessing manikin accuracy.

Ergonomics — Computer manikins and body templates —

Part 2:
Verification of functions and validation of dimensions for computer manikin systems

1 Scope

This part of ISO 15536 establishes the requirements for the verification of the functions and validation of dimensions of computer manikins. These requirements concern the documentation of the data employed to construct computer manikins and the methods employed to verify and validate their functions with regards to their dimensional accuracy.

This part of ISO 15536 extends to anthropometric and biomechanical data and to software functions as they are applied to create computer manikins. Although this document primarily refers to anthropometric data and methods, some biomechanical parameters are required to build and apply computer manikins and are therefore included.

This part of ISO 15536 provides a framework for reporting computer manikin accuracy and human-source data. The standard is intended to enable even non-specialist users of the manikin systems to independently perform measurements of each function under field testing conditions using automated software tools provided by developers.

It is not intended to require developers to perform specific verification and validation of their manikin systems.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments).

ISO 7250:1996, *Basic human body measurements for technological design*

ISO 15535, *General requirements for establishing anthropometric databases*

ISO 15536-1:2005, *Ergonomics — Computer manikins and body templates — Part 1: General requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 15536-1 and the following apply.

3.1
manikin accuracy
manikin accuracy refers to the precision with which a computer manikin system reproduces the size, shape, posture, angles, movement paths and other geometric characteristics of the individual from whom the measurements were taken

3.2
developer
company, institution or individual who develops computer manikin systems

3.3
field-testing conditions
conditions in which the user of the manikin system normally works, typically consisting of a computer workstation in an office environment, and where highly specialized anthropometric and biomechanical laboratory tools and support personnel are assumed to be unavailable

3.4
manikin function
capability of the computer manikin software system to simulate some characteristic, activity or condition of the human body

3.5
measurement landmarks
points located and placed on the human body's surface or on a computer manikin, used for measurement of distance or displacement

3.6
repeatability
extent to which the values of a dimension measured more than once on the same subject are the same

NOTE A completely repeatable function would have a standard deviation of zero.

3.7
manikin verification
activity of confirming that computer manikin functions work as described

3.8
manikin validation
activity of measuring computer manikin accuracy

NOTE For the definition of manikin accuracy, see 3.1.

3.9
digital user documentation
electronic reference material included with the computer manikin system that can be accessed while using the software

4 Requirements for computer manikin verification

4.1 General

The requirements specified in 4.2 to 4.5 are given to enable non-specialist users of a manikin system to independently measure the accuracy of manikin dimensions and to verify the manikin's functions under field-testing conditions using automated software tools provided by manikin system developers.

4.2 Listing of functions

Each computer manikin function identified as being provided by the developer (e.g. interference or reach analyses) shall be listed in a table labelled "List of functions". The list shall be accessible from the digital user documentation.

4.3 Description of functions

A description of each computer manikin function, listed in the "List of functions" table, shall be provided in the digital user documentation. The description shall include the function's intended purpose and boundary conditions of appropriate use.

4.4 Verification of functions — Examples supplied by developers

Each computer manikin function listed in the "List of functions" table shall be accompanied in the digital user documentation by at least one example illustrating and simulating its operation. The example shall permit users to input representative values and observe corresponding output performance.

4.5 Verification of functions — Enabling manikin system user to record/report performance

The user of the system shall be provided with a means to electronically record and report the performance of each function, as defined in 4.3, in a standard digital format suitable for output to standard printing devices. A means shall be provided for automatically generating a report each time a function is tested. The report shall include the values input by the user and the function's output performance.

5 Requirements for documenting source data

5.1 Listing of parameters

Each computer manikin function that employs measurements of human characteristics shall identify the parameter's name and units of measurement. Each parameter shall be listed by name in a table labelled "List of human data parameters" and be accessible from the digital user documentation.

5.2 Parameter description

Each data parameter listed in the "List of human data parameters" table shall be accompanied in the user documentation by a description of its statistical characteristics and method of measurement. The nomenclature, landmarks and measurement methods of ISO 7250 shall be employed, where appropriate.

The statistical description of each parameter in the human data set shall include its source, sample size, minimum and maximum values, mean, mode, standard deviation, and 1^{st}, 5^{th}, 50^{th}, 95^{th}, 99^{th} percentile values; if information is not available, this shall be stated explicitly. If the data parameter is from a publicly available data set, the source publication shall be referenced.

5.3 Sampling method

Each data parameter listed in the “List of human data parameters” table shall describe the methods employed to sample (select) individuals from the subject population for measurement; if the information is not available, this shall be stated explicitly.

5.4 Sample demographics

Each data parameter listed in the “List of human data parameters” table shall identify the sex and age of the individuals measured in accordance with ISO 15535; if the information is not available, this shall be stated explicitly. If population segments, occupation, or other demographic variables are used to define model parameters, they shall also be listed.

6 Requirements for computer manikin validation

6.1 General requirements

Automated software tools shall be provided to support the measurement and reporting of manikin system accuracy and repeatability by users under field-testing conditions.

In order for a specific manikin function or characteristic to be in compliance with this part of ISO 15536, the developer shall have provided methods for manikin measurement and data documentation in accordance with its requirements. Compliance does not ensure the accuracy of any specific manikin, but only indicates that the user can test manikin accuracy.

This document takes no position on which measures or measurement conditions are preferred for validation, due to the extremely large number of manikins, sizes, shapes, postures and conditions that would need to be tested to satisfy all users and their diverse applications.

6.1.1 Measurement landmarks

Landmarks and reference planes necessary in order to perform the human body measurements in accordance with ISO 7250:1996, Clause 4, shall be placed on each computer manikin or appropriate planar surfaces with provisions to toggle them on or off.

6.1.2 Adding new measurement landmarks

A means shall be provided to add new measurement landmarks to manikin structural elements for the purpose of making automated manikin measurements. Each user-created landmark shall have the same functional characteristics as the landmarks specified in 6.1.1.

6.1.3 Listing of landmarks

Each measurement landmark provided in or added to the manikin system shall be listed in a table labelled “List of measurement landmarks” and shall be accessible from the digital user documentation.

6.1.4 Measurement reporting

All computer manikin parameters listed in the “List of human data parameters” table shall be provided with a means for automatically measuring and reporting their accuracy. If a means for the automatic measurement of dimension values is not provided, this shall be stated explicitly.

6.1.5 Manikin accuracy

The user shall be provided with a means to calculate the accuracy of each parameter. The manikin accuracy is calculated as the difference between the input and output values for a particular manikin dimension in terms of difference and percent error (see ISO 15536-1:2005, 6.4). Input values are measured from landmarks placed on an actual person, while output values are measured from corresponding landmarks (see 6.1.1) on the manikin which were created to represent the person whose measurements were used as the input. Input values should be based on the average of at least three measurements.

Difference errors, e_{dif}, is expressed as the difference between the input and output values:

$$e_{\text{dif}} = V_{\text{out}} - V_{\text{in}}$$

where

V_{out} is the output value;

V_{in} is the input value.

The percentage error, e_{p}, is expressed as a percentage of the input value, in accordance with ISO 15536-1:2005, 6.4:

$$e_{\text{p}} = \frac{V_{\text{out}} - V_{\text{in}}}{V_{\text{in}}} \times 100$$

6.1.6 Repeatability

The user shall be provided with a means to calculate the repeatability of each parameter.

A recommended metric of repeatability is the standard deviation of a function's output values when calculations are repeatedly performed with a small sample size such as 10. For example, the measurement of a parameter from a single individual would be input to a function ten times and the resulting output would be observed for variability.

6.1.7 Field-test condition measurement support

Annexes A and B are provided to help users make independent measurements of manikin accuracy and repeatability under field-testing conditions relevant to their specific equipment-design applications.

6.2 Static functions

A general approach, recommended for validation testing of dimensional and angle measurements for static functions, is provided in Annex B.

6.2.1 Static testing of manikin dimensions

The capabilities described in 6.2.1.1 to 6.2.1.4 shall be provided to support the user's need to validate application-specific manikin features in the field.

6.2.1.1 Linear measurements

A means shall be provided to make horizontal and vertical distance measurements and shortest-distance measurements between any of the landmarks specified in 6.1.1 and 6.1.2.

6.2.1.2 Angular measurements

A means shall be provided for users to perform angular range-of-motion measurements for each angular parameter for each manikin joint. Flexion, extension and torsion angles shall reference each measurement to the axis of the adjacent body link. A recommended framework for describing angular characteristics of body segments and joint movements is described in Annex A.

6.2.1.3 Reach functions

Manikins having a “reach” function shall describe the type of reach (e.g. maximum) and provide a means of measuring each manikin’s functional-reach limits and of comparing the manikin’s reach performance with input data from subjects performing the same reach actions under the same conditions. In the validation of effort-dependent and posture-dependent functions such as reach, it is particularly important that the dimensions of the manikin and the subject match each other.

6.2.1.4 Automated comparisons

An automated means shall be provided for comparing each anthropometric and biomechanical parameter measured from individuals with their corresponding computer-manikin representations in accordance with 6.2.1.2 and 6.2.1.3.

6.2.2 Clothing or attached personal protective equipment

Computer manikins that enable the modelling of clothing or personal protective equipment such as helmets, breathing apparatus or communications gear shall provide a means of measuring the dimensional accuracy of these manikin-object systems.

6.3 Reporting test results

All automated measurements shall be available for output in a standard electronic file format. The report shall list each measured parameter and include its calculated percent error, difference error and repeatability.

Annex A
(informative)

Recommended nomenclature and definitions of joint movements for modelling humans

A.1 Introduction

In order to realise the smooth and reliable data import-export between different computer manikin systems, and to create a linkage between observation of the movements of the test persons and movements of the manikin, the same co-ordinate systems and the same definitions of human movements should be used. They therefore need to be consistently defined. The nomenclature and definitions given in A.2 to A.6 are recommended for constructing manikins and for measuring data of real humans for modelling humans.

More than one term is used to describe the movements and alternative terms are given in parentheses.

A.2 Basic planes

The basic planes are shown in Figure A.1.

A Horizontal planes (transverse planes): cross-sectional planes of the body.

B Mid-sagittal plane: vertical plane in the anterior-posterior direction that divides a person assuming a neutral body posture into equal left and right halves.

C Frontal planes (coronal planes): vertical planes of the body orthogonal to both horizontal and median planes.

D Sagittal planes: planes parallel to mid-sagittal plane.

A.3 Basic axes

The basic axes are shown in Figure A.1.

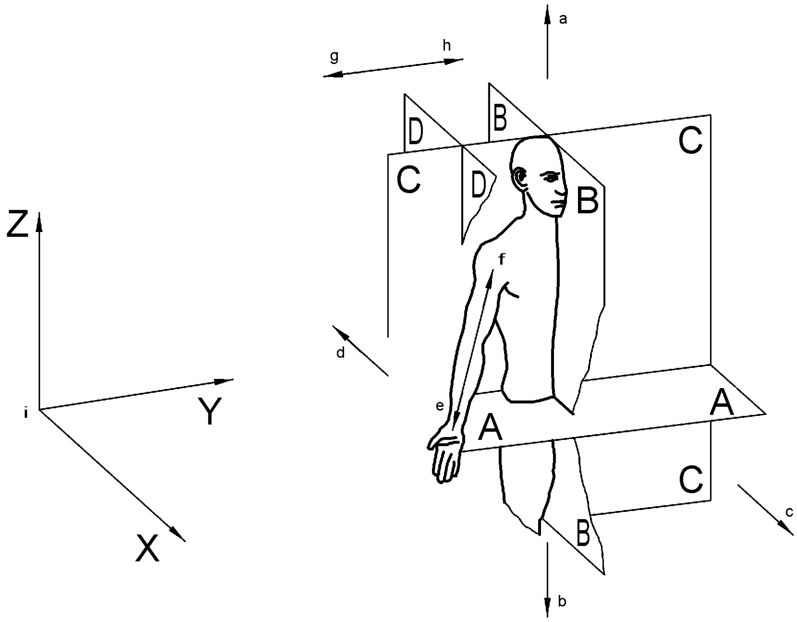
Sagittal horizontal axis (anterior/posterior axis) (X) is directed from back to front of the body (from posterior to anterior).

Frontal horizontal axis (transverse axis, lateral axis) (Y) is directed laterally from the right to the left of the body.

Vertical axis (inferior/superior axis) (Z) is directed from down to up (from inferior to superior) of the body when standing.

Proximal refers to the parts closer to the centre of the body and distal to the parts further away from the mass centre of the body.

For the definitions of sagittal, frontal, anterior, posterior, inferior, superior, distal, proximal, lateral and medial, see ISO 7250.



Key

A horizontal plane (transverse plane)
B mid-sagittal plane
C frontal plane
D sagittal plane

X sagittal horizontal axis (anterior/posterior axis)
Y frontal horizontal axis (transverse axis, lateral axis)
Z vertical axis (inferior/superior axis)

[a] Superior.
[b] Inferior.
[c] Anterior.
[d] Posterior.
[e] Distal.
[f] Proximal.
[g] Lateral.
[h] Medial.
[i] Co-ordinate system, in which the direction of the arrows indicates positive values.

Figure A.1 — Basic planes and axes of the body

A.4 Co-ordinate system

Different CAD systems make use of a variety of co-ordinate systems. It is thus important that the developer of the computer manikin system specify the co-ordinate system used in the creation of the manikin.

A.5 Basic posture

Basic posture is a standing position with the palms towards front and the head held upright, i.e. in the position of the Frankfurt plane, see ISO 7250 (and Figures A.2 and A.3). This posture is the starting position for those presented joint movements, and their angles are defined as zero degree in this position except for the rotative movements of pronation and supination of the hand (see A.6.4). Basic posture as described here is intended only for defining the movements and angles, not for the appearance of the manikin.

The angle unit used should be degrees.

A.6 Angular definitions of joint movements

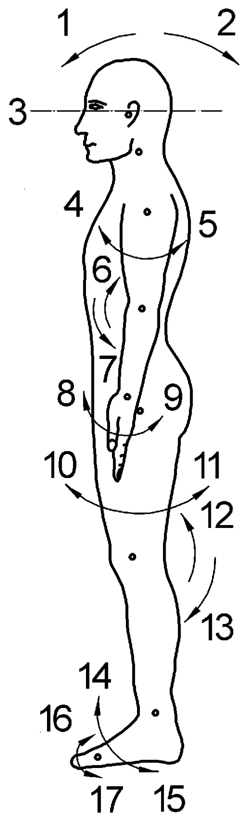
A.6.1 Flexion and extension

At the basic posture (see Figure A.1), flexion and extension are defined as movements in a sagittal plane. For the head, upper body and hip, a movement which closes two adjacent segments towards front is defined as flexion, and the opposite movement is defined as extension. At the knee and ankle joints the directions are inverted. Flexion is expressed by positive values (+) and extension by negative values (–). See Figure A.2.

Besides this systematic terminology, following terms are used:

- for flexion of the wrist, palmar flexion of the wrist;
- for extension of the wrist, dorsal flexion (or dorsiflexion) of the wrist;
- for flexion of the ankle, plantar flexion of the ankle;
- for extension of the ankle, dorsal flexion (or dorsiflexion) of the ankle.

Differing from the basic system, the horizontal movement of the upper arm at the shoulder joint from lateral towards forward (see Figure A.4) is defined as horizontal flexion (+), and the opposite movement as horizontal extension (–). The same terms apply also for the horizontal movement of the thigh at the hip joint (e.g. in seated position).



Key

1 flexion of neck (forward bending of neck) (+)
2 extension of neck (backward bending of neck) (−)
3 Frankfurt plane
4 flexion of shoulder (+)
5 extension of shoulder (−)
6 flexion of elbow (+)
7 extension of elbow (−)
8 palmar flexion of wrist (flexion of wrist) (+)
9 dorsal flexion of wrist (extension of wrist) (−)
10 flexion of hip (+)
11 extension of hip (−)
12 flexion of knee (+)
13 extension of knee (−)
14 dorsal flexion of ankle (extension of ankle) (−)
15 plantar flexion of ankle (flexion of ankle) (+)
16 dorsal flexion of forefoot (−)
17 plantar flexion of forefoot (+)

Attention is drawn to the plus or minus signs between parentheses.

NOTE Flexion and extension of the trunk are not indicated in this figure.

Figure A.2 — Definition of flexion and extension

A.6.2 Abduction and adduction

Abduction and adduction are movements in a frontal plane. Abduction is a movement in which the segment is going away from the trunk, while adduction is an approaching motion of the segment towards the trunk. Adduction is expressed by positive values (+) and abduction by negative values (–). See Figures A.3 and A.4.

Besides this systematic terminology, following terms are used:

— for radial abduction of the wrist, radial deviation (or radial flexion) of the wrist;

— for radial adduction of the wrist, ulnar deviation (or ulnar flexion) of the wrist.

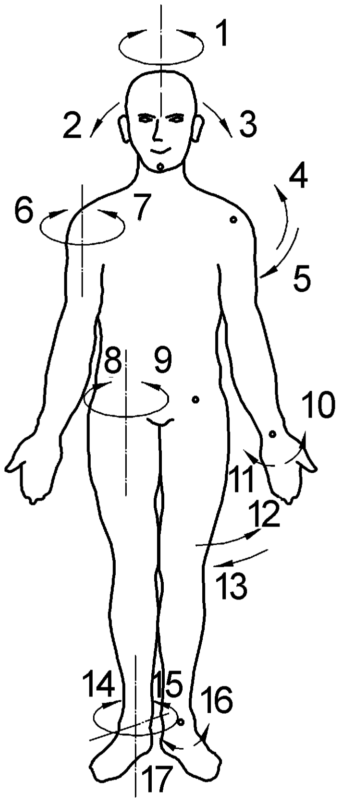
Abduction of the foot is lateral outward rotation of the foot around the axis of the lower leg. Adduction is the opposite movement. Abduction is expressed by negative (–) and adduction by positive (+) values. This movement is not only a movement of the ankle joint but also the result of lateral and medial rotation of the hip (when standing), or of lateral and medial rotation of the knee (when sitting) (see A.6.3).

A.6.3 Lateral and medial rotation

In lateral shoulder rotation or hip rotation the upper arm or the thigh rotates around its longitudinal axis so that the front surface of the segment moves away from the median plane. In medial rotation the movement is inverted. Lateral rotation is expressed by a negative value (–) and medial rotation by a positive value (+). Outward rotation is a synonym for lateral rotation and inward rotation is a synonym for medial rotation. See Figure A.3.

The lateral rotation of the foot is used when the whole foot rotates laterally around its longitudinal axis at the ankle joint away from the median plane. The lateral rotation in which the foot turns outward has a negative value (–), while the medial rotation, in which the foot turns inward, a positive value (+).

For the lateral and medial rotation of the foot, the terms eversion and inversion are also used, respectively. Eversion means a combination of plantar flexion, abduction and pronation, while inversion is a combination of dorsal flexion, adduction and supination.



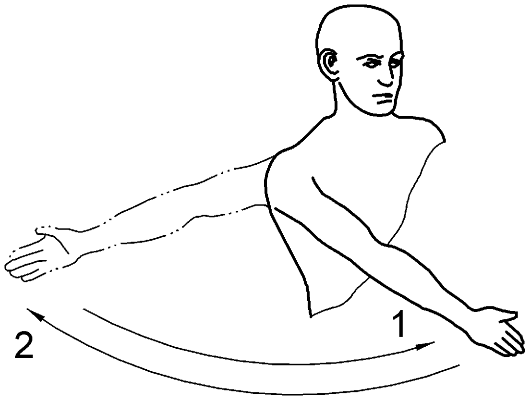
Key

1 rotation of head (and neck)
2 lateral flexion (side-bending) of head (+)
3 lateral flexion (side-bending) of head (−)
4 abduction of shoulder (−)
5 adduction of shoulder (+)
6 lateral rotation of shoulder (−)
7 medial rotation of shoulder (+)
8 lateral rotation of hip (−)
9 medial rotation of hip (+)
10 radial deviation (abduction) of wrist (−)
11 ulnar deviation (adduction) of wrist (+)
12 abduction of hip (−)
13 adduction of hip (+)
14 abduction of foot (−)
15 adduction of foot (+)
16 lateral rotation of foot (−)
17 medial rotation of foot (+)

Attention is drawn to the plus or minus signs between parentheses.

NOTE Lateral flexion of the trunk is not indicated in this figure.

Figure A.3 — Abduction, adduction, lateral rotation and medial rotation at the basic standing position



Key

1 horizontal flexion (+)

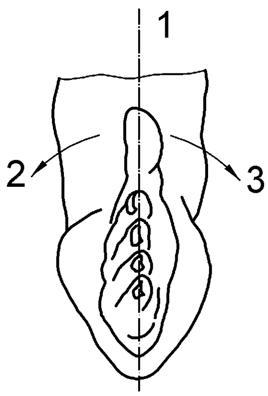
2 horizontal extension (−)

Figure A.4 — Horizontal flexion (horizontal adduction) and horizontal extension (horizontal abduction) of upper arm at shoulder joint

A.6.4 Pronation and supination

Pronation of the hand is, taking the case of the right hand viewed from the elbow, the anticlockwise (counter-clockwise) rotation of the hand. Supination is the opposite movement. At the neutral position shown in Figure A.5, the degree is zero.

Pronation and supination of the foot are twisting movements of the foot around its longitudinal axis, i.e. the forefoot in relation to the heel. Pronation means twisting of the forefoot so that the front or upper surface of the foot moves towards the median plane (inwards). In supination the movement is inverted. For pronation, a positive value, and for supination, a negative value (−), should be applied.



Key

1 neutral position (0 degrees)

2 supination (−)

3 pronation (+)

Figure A.5 — Pronation and supination of the hand

A.6.5 Movements of thumb and fingers

A.6.5.1 Flexion and extension of the four fingers

For the flexion and extension of the four fingers without the thumb, the basic rule shown in Figure A.2 applies.

A.6.5.2 Abduction and adduction of the four fingers

In the case of abduction and adduction of the four fingers, the middle finger does not move and plays the role of the trunk. These movements are applied to the index finger, the ring finger and the small finger. For the movement of the middle finger itself, radial abduction and ulnar abduction are applied. See Figure A.6.

A.6.5.3 Flexion and extension of the thumb

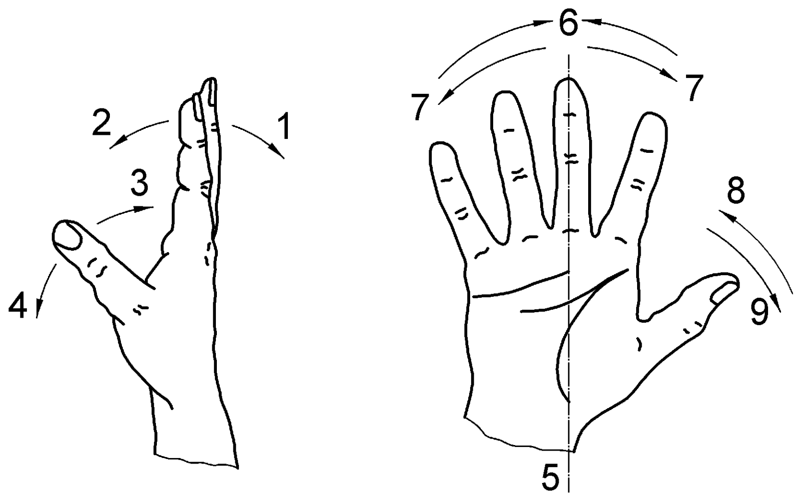
The flexion and extension axis of the thumb is orthogonal to the axis of the four fingers, and its movement plane is parallel to the palm. See Figure A.6.

A.6.5.4 Abduction and adduction of the thumb

Abduction of the thumb is a movement in which the thumb is moving orthogonally away from the palm, and adduction is an approaching movement toward the palm. See Figure A.6.

A.6.5.5 Opposition of the thumb against the other fingers

Opposition of the thumb is medial rotation of the metacarpal bone of the thumb toward the palm. Opposition of the small finger is a slight medial rotation of the metacarpal bone of the small finger toward the palm. Opposition has positive values (+) and the opposite movement negative values (–).



Key

1 extension of fingers (–)

2 flexion of fingers (+)

3 adduction of thumb (+)

4 abduction of thumb (–)

5 reference line (middle finger)

6 adduction of fingers (+)

7 abduction of fingers (–)

8 flexion of thumb (+)

9 extension of thumb (–)

Figure A.6 — Movement of the thumb and fingers

A.6.6 Movements of head, neck and trunk

A.6.6.1 Flexion and extension of head, neck or trunk

Flexion (forward bending) of the head, neck or trunk are indicated by a positive value (+), and extension (backward bending) by a negative value (–).

A.6.6.2 Lateral flexion of head, neck and trunk

Lateral flexion (lateral bending, side bending) of the head, neck and trunk to the right should be indicated by a positive value (+), and to the left by a negative value (–).

A.6.6.3 Horizontal rotation of the head, neck or trunk

Horizontal rotation of the head, neck or trunk (turning of the head, twisting of neck and trunk) to the right (clockwise rotation seeing from top) should be indicated by a negative value (–), and to the left by a positive value (+).

Annex B
(informative)

Static-test protocol

The general approach recommended for validation testing of static measurements is the following.

a) Select several individuals who are representative of the intended subject population (see ISO 15537).

b) Place measurement landmarks on each subject (see ISO 7250:1996, Clause 4). Measure each dimension of interest at least three times for each individual (to estimate the mean value) using the landmarks. See ISO 7250 for a description of the measurement methods and landmarks.

c) Input the measured anthropometric values (an average value based on at least three observations per dimension) into the manikin-creation system to produce a computer manikin of the individual measured.

d) Using the tools provided by the software and referencing the landmarks provided by step b), measure the same parameters on the computer manikin that were measured on the test person and used as input to create the manikin. If repeatability is being computed, create the manikin at least ten times, using identical input values, and measure the output values each time to compute the standard deviation.

e) To assess accuracy of the manikin parameters and applications, compute the errors between the test person measurement and the computer manikin representation using the automated measurement software provided with the computer manikin system.

f) To assess the repeatability (reliability) of the manikin creation system, calculate the parameter’s repeatability using the automated measurement software provided with the computer manikin system.

g) Create a report that summarizes the accuracy and repeatability of values measured from the human and the computer manikin system.

h) Users determine the acceptable levels of accuracy and repeatability needed for their specific applications.

This process should be repeated for all critical postures where the user of the manikin system requires high degrees of accuracy. At a minimum, the postures of standing, sitting and the most critical working postures should be assessed to assure the manikin system is performing as expected and with the needed accuracy.

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