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Ergonomics — Accessible design — Ease of operation

Ergonomie — Conception accessible — Facilité d'emploi

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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.

Introduction

Operation of products and equipment used in everyday life requires a range of human physical characteristics and capabilities. The range is broad, including very limited capabilities among parts of the population. To improve operating accessibility, products and equipment must be designed using ergonomic principles related to physical characteristics, capabilities and limitations among populations.

This document provides ergonomic considerations for design to increase the operating accessibility of products and equipment specific to human physical characteristics, capabilities and limitations (e.g. body size, reach range, strength, dexterity).

This document adopts the guidance on accessibility given in ISO/IEC Guide 71 and ergonomics data given in ISO/TR 22411.

Ergonomics — Accessible design — Ease of operation

1 Scope

This document provides ergonomic requirements and recommendations for increasing accessibility in terms of ease of operation through the design of products and controls of daily use. It is intended to aid the design of products and equipment that can be handled and manipulated easily and comfortably by people with the widest range of physical characteristics, capabilities and limitations across the widest age range.

The requirements and recommendations specified in this document are based on general accessibility considerations as well as specific design considerations based on human physical characteristics, capabilities and limitations related to the operation of products and equipment, such as body size, strength, reach range and dexterity. Some considerations of cognitive factors are also presented.

Products and equipment for professional use only, as well as those used only by technical experts, are not covered in this document. Design aspects related only to information and marking are not included.

This document includes no general ergonomic requirements or recommendations for manual handling, working postures or safety of machinery but the contents are based on general knowledge of those issues.

NOTE ISO 11226, ISO 11228-1, ISO 11228-2, ISO 11228-3, EN 894-3+A1, EN 1005-2, EN 1005-3, EN 1005-4 and EN 1005-5 provide ergonomic requirements and recommendations for manual handling, working postures and safety of machinery.

2 Normative references

ISO 20282-1:2006, *Ease of operation of everyday products — Part 1: Design requirements for context of use and user characteristics*

IEC 63008:2020, *Household and similar electrical appliances — Accessibility of control elements, doors, lids, drawers and handles*

EN 301 549, V3.1.1:2019, *Accessibility requirements for ICT products and services*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

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

3.1
control
element of a product with which a user operates the product

EXAMPLE Buttons, levers, knobs.

3.2
control panel
board that integrates controls, including information and marking

3.3
information and marking
visual or tactile characters and symbols, written or spoken instructions, and other indicators provided with the product to assist the user with its operation and use

EXAMPLE Labels, meters, indicators.

3.4
operation
action that a user performs to achieve an intended goal supported by the predefined behaviour of the product

EXAMPLE Lifting, lowering, carrying, gripping, rotating, pushing, sliding, touching.

Note 1 to entry: See Annex A.

3.5
ease of operation
extent to which a product, control or control panel is used with ease and comfort

4 General requirements

4.1 General

Subclauses 4.2 to 4.10 provide general accessibility requirements and recommendations for ease of operation. The design of products, controls and control panels shall take into account these requirements and recommendations.

Considerations on user characteristics related to everyday products shall be in accordance with ISO 20282-1:2006, Clause 7.

Safety issues in general shall take precedence over any accessibility requirements and recommendations.

4.2 Layout of controls and control panels

Placing a control and a control panel for users to access without bending or stretching increases accessibility, accommodating the widest range of seated and standing anthropometry (including use of a wheelchair) to the product. A control or control panel that is prominent and identifiable also increases accessibility. See also 5.4.

The following specific design requirements and recommendations are intended to increase accessibility related to location and layout of a control or control panel:

— The position of a product's control or control panel should be recognizable from the user's field of view when he or she is looking at the whole product. See 5.4.3.

— The top–bottom and left–right orientation of a control panel shall be identifiable.

  EXAMPLE A tactile marking at the top of a control panel to show upwards for people with limited visual abilities.

— A product control or control panel shall be located within reach of a user's position. See 5.4.1 and 5.4.2.

— A product control or control panel should be identifiable by its particular shape.

  EXAMPLE An input control with a large push-button.

— A control should be located in a position that is not hidden by the user's hands during operation.

NOTE Operation includes actions of various types, such as with a single hand, both hands and hands with low dexterity, and some actions interfere with seeing or touching a control.

— A control or control panel should have sufficient spacing around it so that the user's fingers or hands do not interfere with the operation or with nearby controls or control panels.

— The layout of a control or control panel should be logical and consistent with regard to frequency and process of use.

EXAMPLE Controls aligned in a sequential order or placed in a group, along with frequency of use.

— Controls should be grouped by a common shape, size and colour when coordinated in operation.

— Each control should have a single function.

— When more than one function is assigned to a single control, information and marking shall be provided to show the functions.

— Specific controls such as keyboard keys or buttons in a control panel of a product which serve as "home" keys or buttons should be identifiable with surface features facilitating tactile identification.

EXAMPLE A raised dot on the "5" key in a numeric keypad.

4.3 Strength required for operation

Considerations of population strength characteristics, such as age, sex and physical capabilities and limitations, for operation of a product and controls that require user strength output (e.g. holding, gripping, pushing, sliding) increase accessibility.

The following specific design requirements and recommendations are intended to increase accessibility related to human strength. For the strength of each particular action, see Clause 5.

— Strength for operating a product should be set at the minimum suitable force required for comfort control.

— A product that needs excessive strength for operation should have an additional device to assist, thereby decreasing the required strength.

NOTE Some people with physical limitations of the upper or lower limbs, in particular people with rheumatism or spinal cord injuries, are unable to operate some products.

— When operation of a product requires opening and closing, the actions should require minimal strength to be accessible by the widest range of population (e.g. age, sex, strength limitations), except where a fail-safe mechanism and safety considerations are needed (see 4.9).

— Products, controls and control panels shall have a non-slippery surface finish with purchase for hands or fingers to make operation easier for people with muscle strength limitations.

— When a product uses a touch screen, care should be taken with the appropriate pressing strength.

4.4 Dexterity

Considerations of user's finger or hand dexterity increases accessibility to ease operation for the widest range of users, including people with dexterity limitations.

The following specific design requirements and recommendations are intended to increase accessibility related to dexterity:

— A control should be designed to be operated by people with the widest range of dexterity capabilities and limitations, including those in a higher age range or with compromised dexterity abilities.

— A control that needs fine dexterity for operation should have an assistive tool or an indicator, such as a visual scale, to guide the operation.

— Use of different time durations for different operations on the same control, such as a long and a short pressing time, should be avoided except for particular cases, such as avoiding incorrect operation or using long and short pressing times to denote different control functions (such as in touch screens).

NOTE The dexterity is sometimes negatively affected by wearing gloves.

4.5 Avoidance of simultaneous multiple operations

Multiple operations should not be imposed at one time on one operating part of a product.

The following specific design requirements and recommendations are intended to increase accessibility related to avoidance of simultaneous multiple operations:

— Simultaneous multiple operations, such as pressing and rotating, should not be used except to ensure safety and to prevent misuse, for example in the case of child-resistant products.

— An alternative method of operation should be provided when simultaneous multiple operations are provided (see 4.6).

4.6 Provision of multiple means of operation

Provision of multiple means for operating a product or control increases accessibility, enabling the widest range of users to use the product.

The following specific design requirements and recommendations are intended to increase accessibility related to multiple means of operation:

— A product should have multiple means of operation for its main parts.

EXAMPLE 1 An input control using either a keyboard, a touch screen or a voice input.

EXAMPLE 2 Operation which requires touching with two fingers can be carried out by touching with just one finger.

— Compatibility with assistive devices for people with physical limitations should be made possible.

4.7 Provision of feedback

Provision of feedback for operating a control increases accessibility.

The following specific design requirements and recommendations relate to the provision of feedback:

— Operation of a control should prompt acceptance or response feedback to the user through multiple means of information (e.g. visual, auditory, tactile or haptic).

EXAMPLE A response to show “accepted” or “error” by means of a visual display or an auditory signal.

— For a series of operations, feedback should be given to the user after each operation, together with information related to the status or stage of the operation.

— For a cyclic series of operations, information related to a starting and an ending stage should be provided.

EXAMPLE A rotating dial control that stops at an ending stage.

— Reaction time for feedback shall be constant for a group of related operations.

— Tactile or haptic feedback should be used for people with limited visual or hearing abilities.

EXAMPLE A short vibration used for a touch screen input device when operated with a finger.

— When tactile vibration is used as feedback, care should be taken to avoid excessive vibration that causes discomfort and other problems for human touch.

— The direction and amount of movement of a control should correlate with the resulting change(s) in a product or an indicator.

EXAMPLE Clockwise rotation of a control denoted by a clockwise turning scale.

4.8 Logical process

Provision of logical and straightforward processes for operating a product increases accessibility when a sequence of operations is required.

The following specific design requirements or recommendations are intended to increase accessibility related to the logical process of operating a product:

— Complicated multiple steps in hierarchical processes for operating a product should be avoided.

— Unnecessary repeated actions shall be avoided. If repeated actions are necessary, the times repetition is necessary should be reduced.

EXAMPLE Use of a single combined operation when the operation is always followed by two or three of the same sequential operations except for ensuring safety.

— An “undo” function shall be possible for a sequence of operations to stop at any stage and to restart the sequence from the first operation.

EXAMPLE A press button provided to return to the initial stage of a series of operations at any time.

— A set duration of a timed response for an operation shall be sufficiently long to allow an unfamiliar or untrained user to operate it comfortably. Notification of a limited time or a residual time for the operation as well as manual setting for a preferred time by a user should be provided.

— Programmable settings for frequent sequential operations should be provided. The programme should be able to be easily started and edited by a user.

NOTE A set of sequential operations fixed in a programme is effective for people with limited cognitive abilities.

— The shape and placement of a control or control panel should be designed so the user intuitively understands the action which is necessary for its operation.

EXAMPLE A small tab attached to a package that is meant to be pulled.

— A paired operation of a product should be used for easy and intuitive understanding of the mutual relation of the operations.

EXAMPLE A control using a toggle switch for “ON” and “OFF”, “UP” and “DOWN” or “LEFT” and “RIGHT”.

4.9 Safety and a fail-safe mechanism

Considerations to ensure safety and a fail-safe mechanism increase accessibility.

The following specific design requirements and recommendations are intended to increase accessibility related to safety and a fail-safe mechanism:

— A control should be designed to be operated with the minimum suitable force that avoids inadvertent and unintentional activation.

NOTE People with limited visual abilities can press control buttons unintentionally.

— Reach range, body size and the user position shall be taken into account to avoid unintentional activation of a control.

— A control shall be placed apart from other controls or have a lock mechanism or a cover to avoid unintentional operation.

EXAMPLE 1 A nurse call button in a hospital that is isolated from other controls.

EXAMPLE 2 A lighter with a child-resistant mechanism that is difficult for a child to ignite.

EXAMPLE 3 An emergency push-button with a cover to avoid inadvertent operation.

— A product shall be designed to stop its operation in a safe and non-harmful state after incorrect operation.

— Warning or caution shall be provided to inform users of the state of a product through multiple means of sensory information.

— A fail-safe mechanism shall apply to a control, control panel or product.

EXAMPLE A microwave oven that stops warming when the door is opened.

— When incorrect operation occurs in a series of operations, undoing from any point should be made possible.

— Sharp points or sharp edges shall be avoided when designing a product, a control or a control panel.

— Readily visible warning labels explaining the product mass and operation requirements shall be provided when necessary.

EXAMPLE A package that has a label showing mass and a warning.

4.10 Other (assembling, installation, storage and maintenance)

The following specific design requirements and recommendations are intended to increase accessibility related to assembling, installation, storage and maintenance of a product.

— The size, shape and mass of a product shall be designed for easy holding, lifting and carrying (see 5.2).

— A handle or catch for easy holding, lifting and carrying, if attached to a product, should be designed for easy grasping by hands or fingers and for keeping a mass in balance. A heavy product should be provided with additional mechanisms for easy manual handling, for example casters (see 5.2).

— When assembling a product, control, control panel or any other part of a product should be distinguishable in shape and colour for easy understanding of the assembly process.

— A product should be designed for easy installation, mounting and decomposition. Connection of wiring or attachments should also be easy.

— The layout and process of storing a product shall be easy and understandable.

EXAMPLE The packaging of a product which has instructions for storage.

5 Ergonomic requirements and recommendations for ease of operation

5.1 General

Subclauses 5.2 to 5.4 provide ergonomic requirements and recommendations with regard to physical actions for ease of operation when designing products, controls and control panels. Annex A provides a list of design items and human abilities to be considered for accessibility. Annex B provides relevant data of human abilities with figural representations and Annex C textural descriptions of the figures for people with difficulties in visually retrieving the figural information.

For household and similar appliances, in particular their controls such as handles, doors, drawers and lids, the accessibility requirements given in IEC 63008:2020, Clauses 5 to 7 shall apply.

For ICT products, in particular operating parts, the accessibility requirements given in EN 301 549, V3.1.1:2019, 5.5 to 5.9 shall apply.

5.2 Holding, lifting, carrying, pushing or pulling with hands or feet

5.2.1 Shape and size of products

A product that is operated by holding, lifting, carrying, pushing or pulling with hands or feet should have a shape and size suitable for these actions to be easily performed by the widest range of users, taking account of the direction of force, range of movement and posture required to perform the action.

5.2.2 Mass to hold, to lift and to carry with hands

A product that is operated by holding, lifting and carrying with hands should have a mass suitable for these actions to be easily performed by the widest range of users, taking account of the position of the action (e.g. height), direction of force and posture required to perform the action. The acceptable mass should be based on population strength data, including age differences, sex differences and the effects of physical limitations.

A product that has a mass that is difficult or impossible to hold, lift or carry should have a mechanical assisting device, such as a handle or a grip, for ease of action, or should be provided with other means of transportation.

NOTE 1 Data related to the acceptable mass for lifting with two hands and for carrying with one or two hands for male or female persons of different ages have been reported by HQL.[15][16] The data are useful for designing the mass of a whole product or a package that is lifted or carried by hand. See B.3.1 and B.3.2.

NOTE 2 Data related to the maximum strength for lifting a crate in a standing posture for male or female persons of different heights (tall, medium and short) and for different gripping types (side-gripping and bottom-gripping) has been provided by DIN 33411-5. Male persons exert higher strength than female persons do. The middle height condition is optimum for yielding lifting strength for both male and female persons. No significant difference is found between side-gripping and bottom-gripping. The data are useful for setting a limit for the mass of a product for lifting. See B.3.3.

NOTE 3 ISO 11228-1 defines 5 kg as a reference mass for the evaluation of lifting and lowering strength in non-occupational use for children and older people. It also describes 3 kg as a lower limit for applying the standard.

5.2.3 Strength (pushing or pulling with hands or feet)

A product that is operated by pushing or pulling with the hands or feet should be sufficiently strong to make these actions suitable and easy for the widest range of users, taking account of the direction of force, range of movement and posture required to perform these actions. The acceptable strength should be based on population data that include age differences, sex differences and the effects of physical limitations.

NOTE 1 Data related to the maximum strength for pushing or pulling with one or two hands for male and female persons of different ages have been reported by DTI[20] and TU Delft.[21] The strength for pushing and pulling is in the range of 100 N to 400 N for one hand and 100 N to 500 N for two hands, both depending on age. Pushing strength is greater than pulling strength in both cases. The data are useful for designing a door or a cart pushed or pulled by hand, for example. See B.3.4 and B.3.5.

NOTE 2 Data related to the maximum strength for pressing or lifting a bar and a pedal with the feet for male and female persons of different ages have been reported by DTI.[20] The strength is in the range of 50 N to 700 N for male persons and 50 N to 500 N for female persons, depending on age. The highest strength is found in the age range of 20 years to 40 years. Pressing strength on a bar is much higher than the lifting strength on a bar and a pedal. Male persons show higher strength than female persons do. Data are useful for designing brake pedals of pushchairs or trolleys, for example. See B.3.6.

5.3 Gripping, grasping, rotating, twisting, pushing or pulling (with fingers), pinching, sliding and touching

5.3.1 Shape and size of products, controls and control panels

A product, control or control panel that is operated by gripping, grasping, rotating, twisting, pushing or pulling (with fingers), pinching, sliding or touching should have a shape and a size suitable for these actions to be performed easily by the widest range of users, taking account of the direction of force, range of movement, posture required to perform the actions and dexterity.

Shapes or sizes that require high dexterity for operation should be avoided for people with dexterity limitations (e.g. caused by Parkinson's disease or rheumatism).

NOTE 1 Data for the maximum grip diameter measured anthropometrically for the circle made with the thumb and the forefinger for male and female persons of different ages have been reported by TU Delft.[21] The grip diameter measured are in ranges of 39 mm to 43 mm (male) and 36 mm to 39 mm (female), both showing a gradual decrease with age. These data can be used for the design of grip size for products such as rails, handles and umbrellas. See B.3.7.

NOTE 2 Grips of different diameters are in practical use in different design fields depending on the context of use. Table 1 presents data for some examples.

Table 1 — Grip diameters for handrails

Context of use	Diameter mm	Sources
Handrails in built environment (circular shape)	45 to 60	ISO 21542
Handrails in built environment (elliptical shape)	50 to 70 (width) 25 to 50 (depth)	ISO 21542
Handrails used for assistive products	25 to 45	ISO 17966
Rounded poles (in ergonomic experiments)	30 to 40	HQL[16]

NOTE 3 Data for steadiness of hand–eye coordination as related to dexterity for male and female persons of different ages have been reported by TU Delft.[21] The steadiness was measured using a task in which a thin needle was inserted into a hole without touching the hole edge. This hand–eye coordination gradually deteriorates with age, which means that dexterity decreases with age. The data are useful for designing pointing devices for computers and ticket inserting machines, for example. See B.3.8.

NOTE 4 The maximum angle of inward rotation (pronation) and outward rotation (supination) of the wrist for male and female persons of different ages have been reported by TU Delft.[21] Reduction of the movable range with age is found for outward rotation, with no significant change for inward rotation. The wrists of female persons are more flexible than those of male persons. Data are useful for designing, for example, a rotational knob, a key or a screwdriver. See B.3.9.

NOTE 5 Data for the diameter of a circular dial for ease of rotation with fingers for male and female persons of different ages have been reported by HQL.[18] Data show that a diameter of 20 mm to 25 mm is easily achievable for rotation with the fingers. The data are useful for designing circular dials of household appliances, for example. See B.3.10.

NOTE 6 Data for the preferred stroke length for ease of pushing a small button with the forefinger were reported by Kikuchi et al. for people of different ages.[22] Strokes in the range of 0,5 mm to 1,0 mm were most preferred by people of all ages, with a slight tendency that older people preferred a longer stroke than younger people. The data are useful for designing small push-buttons used for household appliances, for example. See B.3.11.

5.3.2 Strength (hands and fingers)

A product, a control or a control panel that is operated by gripping, grasping, rotating, twisting, pushing or pulling (with fingers), pinching, sliding and touching with hands or fingers should be sufficiently strong for these actions to be performed easily by the widest range of users, taking account of the position of the action (e.g. height), direction of force and posture required to perform the action. The acceptable strength should be based on population strength data that include age differences, sex differences and the effects of physical limitations. Consideration should be devoted to height for wheelchair users, in particular.

A product, a control or a control panel that is operated by the hands and fingers should be designed so that people with limitations of strength or of dexterity of hands or fingers (e.g. because of Parkinson's disease or rheumatism) are able to operate it.

NOTE 1 Data for maximum grip strength for male and female persons of different ages are available from scientific papers[23][24][25] and research project reports (TU Delft,[21] MEXT[26]). Male grip strength is in the range of 100 N to 550 N and female grip strength is in the range of 100 N to 350 N, depending on age. They respectively show the highest values at 20 years to 30 years of age, gradually decreasing with age thereafter. The data are useful for designing products that require squeezing with the hands, such as refuelling hoses and pliers. See B.3.12.

NOTE 2 Data for the maximum twisting strength of the wrist have been reported by NITE[27] and DTI[18] using circular knobs of 50 mm diameter (NITE) and of 40 mm diameter (DTI) for male and female persons of different ages. The necessary twisting strength is in the range of 3 Nm to 5 Nm for male adults and 2 Nm to 4 Nm for female adults, depending on the grip type and knob type. The strength increases with age from 2 years to 20 years until it reaches a plateau, which remains until 60 years of age. It then decreases. No significant difference was found between inward and outward rotation. The data are useful for designing doorknobs, keys and dials for household appliances, for example. See B.3.13.

NOTE 3 Data for the maximum twisting strength of the upper limbs have been reported by NITE.[27] The data were sampled from 38 male persons and 42 female persons who were 60 years to 73 years old. The maximum torque strength is about 5 Nm to 8 Nm for male persons and 3 Nm to 5 Nm for female persons. The necessary torque for inward rotation (pronation) is greater than that for outwards rotation (supination). The data are useful for designing large and heavy handles for household appliances, for example. See B.3.14.

NOTE 4 Data for the maximum torque with two hands for jar opening have been reported by DTI[19] and TU Delft[21] for male and female persons of different ages. The opening torque ranges from 3 Nm to 10 Nm for male adults and from 2 Nm to 6 Nm for female adults, depending on the jar diameter and the lid type. The typical ageing effect is a rather steep increase up to about 20 years, a plateau in adulthood and a gradual decrease with age thereafter. A significant effect is found for the jar diameter and the lid type, i.e. smooth or knurled. The data are directly useful for designing packages. See B.3.15.

NOTE 5 Data for the maximum pushing strength with a finger have been reported by DTI[19] and NITE[27] for male and female persons of difference age groups. The DTI data show strength to be in the range of 120 N to 180 N for male adults and 80 N to 130 N for female adults, whereas NITE data show the range as 40 N to 60 N for male adults and 30 N to 60 N for female adults. This difference depends on the measurement method employed: a force plate for DTI and a real push-button for NITE. No large difference is found between forward and downward pushing, but a significant difference exists between the forefinger and the thumb. The data are useful for designing push-buttons of various types used in home appliances. See B.3.16.

NOTE 6 Data for the maximum pulling strength with a finger have been reported by DTI for a practical case of pulling on a can ring pull.[20] The data were collected from male and female persons of different ages for two ring pull positions: horizontal and vertical to the top of the can (see Figure B.17). The pulling strength is 50 N to 150 N for male adults and 30 N to 100 N for female adults, reflecting the general ageing effect. The data are directly useful for designing the ring pull of a can. See B.3.17.

NOTE 7 Data for pinching strength with fingers have been reported in scientific papers for male and female persons of different ages.[23][24][28] The data are shown for three types of pinching: tip pinch, key pinch and palmar pinch (i.e. three fingers pulp pinch). The pinching strength ranges from 80 N to 120 N for male adults and 50 N to 80 N for female adults, depending on the type of pinching. Data show a general age-related change for a span of life. The key pinch and the palmar pinch yield nearly the same strength. The data are useful for designing clips or controls, for example, that use pinching for operation. See B.3.18.

5.4 Reach range

5.4.1 Height of operation plane of products, controls and control panels

Products, controls and control panels should be placed on a plane at a suitable height that allows ease of operation for the widest range of users, taking account of the type of action and the posture required to perform the action. An acceptable height for the operation plane should be based on population data that includes age differences, sex differences and the effects of physical limitations. Consideration should be devoted to height for wheelchair users, in particular.

NOTE Data for acceptable height of an operation plane have been reported by HQL[18] for the case of vertically pushing a button placed on a horizontal plane. Data are sampled from both male and female persons of different ages when standing and sitting. Whereas female persons prefer the height at olecranon (the lowest elbow point) when sitting, the height of about 90 % of olecranon is preferred for the standing posture by both male and female persons. The acceptable range of height (i.e. between the upper and lower acceptable limit) decreases with age. The data are useful for designing the height of desks, shelves and control panels of house appliances. See B.3.19.

5.4.2 Reach range of the upper limbs

A product, a control or a control panel should be placed so it is reachable or can be operated by the hands or fingers by the widest range of users, taking account of the type of operation and the required posture of the user. An acceptable reach range should be based on population data, taking account of stature, posture (standing or sitting) and effort (comfort or maximum with or without special body motion needed for reaching, such as bending trunk).

The comfortable reach range should be used for cases in which the user's hand or finger frequently reaches a product, control or control panel. The maximum reach range should be used for cases in which the user's hand or finger occasionally reaches a product, control or control panel. In both cases, a product, control or control panel should be placed within the shortest reach range found for the user group.

NOTE 1 Data for the reach range of the upper limbs for simple touching, comfortable and maximum, for groups of different ages and statures have been reported by TU Delft.[21] Data were given for the vertical reach range in a standing posture and for the horizontal reach range in a sitting posture. The effects of age and stature are significant. The reach range becomes smaller with age and with smaller stature. The data are useful for designing kitchen systems, table sizes and window heights, for example. See B.3.20 for vertical reach range and B.3.21 for horizontal reach range.

NOTE 2 Data for the horizontal reach range of the upper limbs for grasping of German female persons in the fifth percentile of body size are provided in DIN/Technical Report 124. Data are given for some different contexts of reaching, such as optimum or extended. The data are useful for design that is related to practical reach range that requires operations such as grasping. See B.3.22.

5.4.3 Useful field of view for finding products, controls and control panels

A product, control or control panel should be located within a useful field of view for the widest range of users, taking account of the contrast, colour differences between a control or control panel and background, and size. An acceptable size of the useful visual field should be based on population data that includes age differences, sex differences and the effects of visual and cognitive limitations.

NOTE Data for useful field of view for simple detection have been reported in ISO/TR 22411 for young (in their 20s) and older (in their 60s to 80s) people. See ISO/TR 22411:2021, 6.2.11.

Annex A
(informative)

Design items to consider accessibility of products related to ease of operation

Table A.1 lists product design features and their related human physical abilities to be considered when addressing operation accessibility.

Table A.1 — Design features and human physical abilities to be considered for accessibility

Product items	Design features	Human actions and abilities
General: whole product whole control panel	Size Shape Mass	Holding, lifting, lowering Carrying Pushing or pulling [by hand(s)] Posture (standing, sitting)
Controls: push-button sliding button (rotating) dial knob handle door	Size Shape Range of movements (e.g. angle) Strength (force or torque) Surface treatment Operation mode (e.g. one-hand) Operation speed Feedback Time constraints Frequency of actions Other (e.g. sharp points)	Pushing or pulling strength Grip size and strength (contact, pinch) Rotating or turning angle Rotating or turning torque and angle of hands (pronation, supination) Dexterity Posture Work efficiency Work effectiveness Coordinated actions
Spatial arrangement	Location Layout	Reach range Dexterity
Other	Illuminance Temperature Surface finish	Visual abilities Thermal sense Tactile sense

Annex B
(informative)

Reference data for human physical characteristics and strength

B.1 General

This annex provides additional information for data of human physical characteristics and strength as referred to in this document. These data are referred from ISO documents, academic papers, technical reports and databases in technical institutions. The data and their reference values are presented as notes in this document because the data depend on the sample body size and contexts of measuring methods and conditions. They are difficult to provide as standard values for general use in a large variety of contexts.

Most of the data presented in this annex are based on the maximum level of human strength, some on comfort levels and some on other criteria in between. The maximum force is not always accepted in designing products as it is the extreme case. In general, the maximum level is greater than the comfort level. It is useful to consider that one third to half of the maximum force can be applied when it has to be exerted many times or comfortably exerted,[29] and much less than that for sustainable exertion depending on the duration. The designer will need to consider the strength data of the specific or appropriate population (e.g. age, gender, disability status) and the conditions in which data are applied.

B.2 Summary of data referred to in this document

Table B.1 includes a list of data referred to in this document. The list is in accordance with the order of Clause 5 and does not necessarily correlate with the logical order of anthropometry. Diagrams of original data, which mostly present average data for groups of persons of different ages, sex and measuring conditions, are presented in B.3. Some data are based on fifth percentiles. For most diagrams, where available, standard deviations are presented as vertical bars to show the variability of the data. The data points with error bars are shifted slightly along the X-axis to display the data clearly.

Table B.1 — Human physical characteristics and capability data

Clause	Notes in main clauses	Data titles in Annex B	Data clauses and figures in Annex B
5.1 General	—	—	—
5.2 Holding, lifting, carrying, pushing or pulling with hands or feet	—	—	—
5.2.1 Shape and size of products	None	No data presented	None
5.2.2 Mass to hold, to lift and to carry with hands	NOTE 1	Lifting strength with two hands with comfort, slight effort and extreme effort	B.3.1 Figure B.1
	NOTE 1	Carrying strength with one or two hands with comfort or slight effort	B.3.2 Figure B.2
	NOTE 2	Maximum lifting strength with two hands	B.3.3 Figure B.3

Table B.1 *(continued)*

Clause	Notes in main clauses	Data titles in Annex B	Data clauses and figures in Annex B
5.2.3 Strength (pushing or pulling with hands or feet)	NOTE 1	Maximum pushing or pulling strength with one hand	B.3.4 Figure B.4
		Maximum pushing or pulling strength with two hands	B.3.5 Figure B.5
	NOTE 2	Maximum pressing or lifting strength with feet	B.3.6 Figure B.6
5.3 Gripping, grasping, rotating, twisting, pushing or pulling (with fingers), pinching, sliding and touching	—	—	—
5.3.1 Shape and size of products, controls and control panels	NOTE 1	Maximum grip diameter	B.3.7 Figure B.7
	NOTE 2	Grip diameter for handrails	Table 1
	NOTE 3	Dexterity: steadiness of hand–eye coordination	B.3.8 Figure B.8
	NOTE 4	Maximum angle of the wrist for inward (pronation) and outward (supination) rotation	B.3.9 Figures B.9
	NOTE 5	Dial diameter for ease of rotation with fingers	B.3.10 Figure B.10
	NOTE 6	Preferred stroke length for pushing a small button with the forefinger	B.3.11 Figure B.11
5.3.2. Strength (hands and fingers)	NOTE 1	Maximum grip strength (of one hand)	B.3.12 Figure B.12
	NOTE 2	Maximum twisting strength of the wrist	B.3.13 Figure B.13
	NOTE 3	Maximum twisting strength of the upper limbs	B.3.14 Figure B.14
	NOTE 4	Maximum jar-opening strength of two hands	B.3.15 Figure B.15
	NOTE 5	Maximum pushing strength with a finger	B.3.16 Figure B.16
	NOTE 6	Maximum pulling strength on a can ring pull	B.3.17 Figure B.17
	NOTE 7	Maximum pinching strength with fingers (tip-pinch, key-pinch, palmar-pinch)	B.3.18 Figure B.18
5.4 Reach range	—	—	—
5.4.1 Height of the operation plane of products, controls and control panels	NOTE	Appropriate height for pushing a button placed on a horizontal plane	B.3.19 Figure B.19
5.4.2 Reach range of the upper limbs	NOTE 1	Vertical reach range of the upper limbs for simple touching while standing	B.3.20 Figure B.20
	NOTE 1	Horizontal reach range of the upper limbs for simple touching while sitting	B.3.21 Figure B.21
	NOTE 2	Reach range of the upper limbs for grasping	B.3.22 Figure B.22

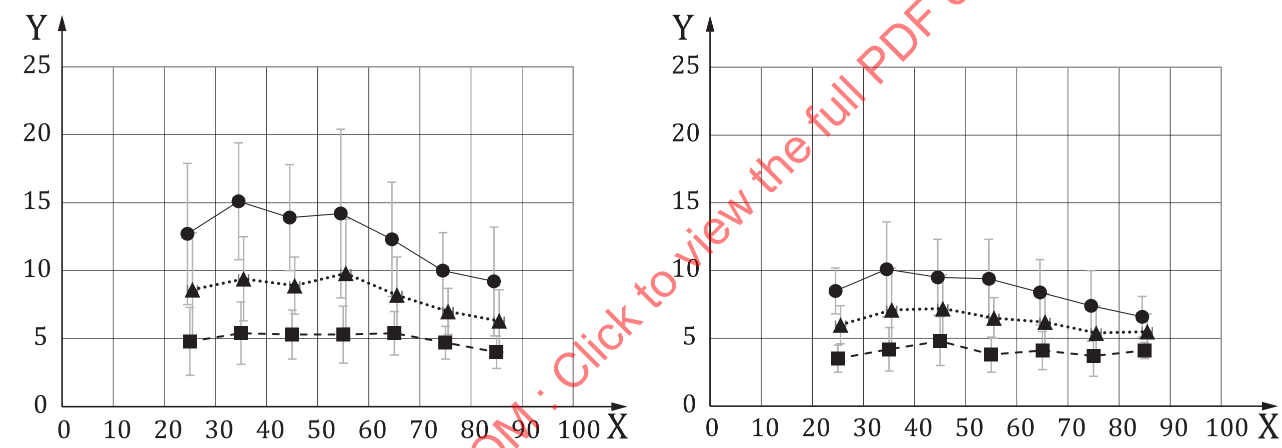
Table B.1 *(continued)*

Clause	Notes in main clauses	Data titles in Annex B	Data clauses and figures in Annex B
5.4.3 Useful field of view for finding products, controls and control panels	NOTE	No data presented	None

B.3 Data

B.3.1 Lifting strength with two hands with comfort, slight effort and extreme effort

Figure B.1 shows data for a mass that a person can lift with two hands against a rectangular solid box of variable mass in a standing posture. The data were obtained from HQL, sampling 214 Japanese persons (109 male and 105 female) aged 20 to 90.[16] Ageing effects were found for lifting a mass with extreme or slight effort, but no significant effects were found for lifting a mass with comfort.



a) Male

b) Female

Key

X age (years)

Y mass to lift (kg)

—●— with extreme effort

···▲··· with slight effort

- -■- - with comfort

NOTE Vertical bars refer to standard deviations.

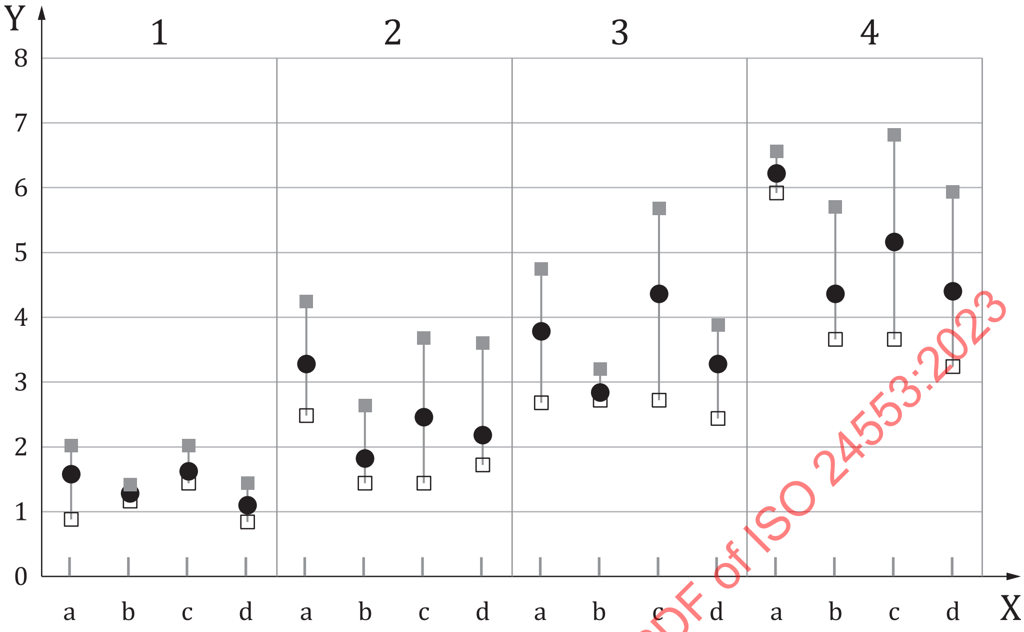
SOURCE Reference [16].

Figure B.1 — Lifting strength with two hands with comfort, slight effort and extreme effort for male and female subjects of different age groups

B.3.2 Carrying strength with one or two hands with comfort or slight effort

Figure B.2 shows data for a mass that a person can carry with one or two hands with comfort or slight effort measured for Japanese people by HQL.[17] The data were obtained by asking the subject to hold a rectangular solid box with variable mass and walk some distance. Eight young people (four aged 20 to

29 and four aged 31 to 39) and 12 older people (three aged 60 to 69, five aged 70 to 79 and four aged 80 to 89) participated. It is clear that carrying strength largely depends on the context of the task.



Key

X	subjects	1	carrying with comfort with one hand
Y	mass to carry (kg)	2	carrying with slight effort with one hand
a	young male subjects	3	carrying with comfort with two hands
b	young female subjects	4	carrying with slight effort with two hands
c	older male subjects		
d	older female subjects		
●	average		
■	maximum value		
□	minimum value		

SOURCE Reference [17].

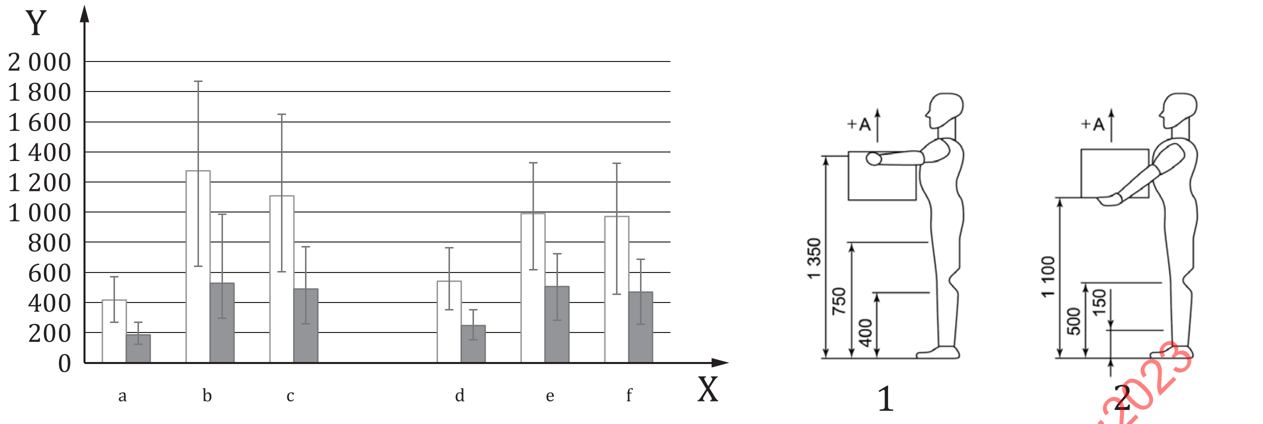
Figure B.2 — Carrying strength with one or two hands with comfort or slight effort for young (20-year-old to 39-year-old) and older (60-year-old to 89-year-old) male and female subjects

B.3.3 Maximum lifting strength with two hands

Figure B.3 shows the maximum lifting strength measured for male and female persons for different gripping types and heights.[14] The strength was measured by lifting a crate (560 mm width) with two hands in two ways (side-gripping and bottom-gripping) at three different heights (low, middle and high), as shown in the inset. Data were sampled from a total of 1 967 male and 1 113 female persons in Germany and the 50th percentile data for male and female groups are shown. The data are also cited in ISO/TR 22411.

The maximum lifting strength of male subjects was found to be greater than that of female subjects depending on the type and height of lifting. The optimum condition for exerting lifting strength is the middle-height condition (from the knee to under the chest). The difference between side-gripping and bottom-gripping remains unclear, particularly for female subjects.

Dimensions in millimetres



Key

X	type of gripping and height	1	side-gripping
Y	lifting strength (N)	2	bottom-gripping
□	male subjects	+A	direction of force
■	female subjects		
a	side-gripping, height = 1 350 mm		
b	side-gripping, height = 750 mm		
c	side-gripping, height = 400 mm		
d	bottom-gripping, height = 1 110 mm		
e	bottom-gripping, height = 500 mm		
f	bottom-gripping, height = 150 mm		

NOTE Vertical bars refer to the fifth and the 95th percentiles of the data.

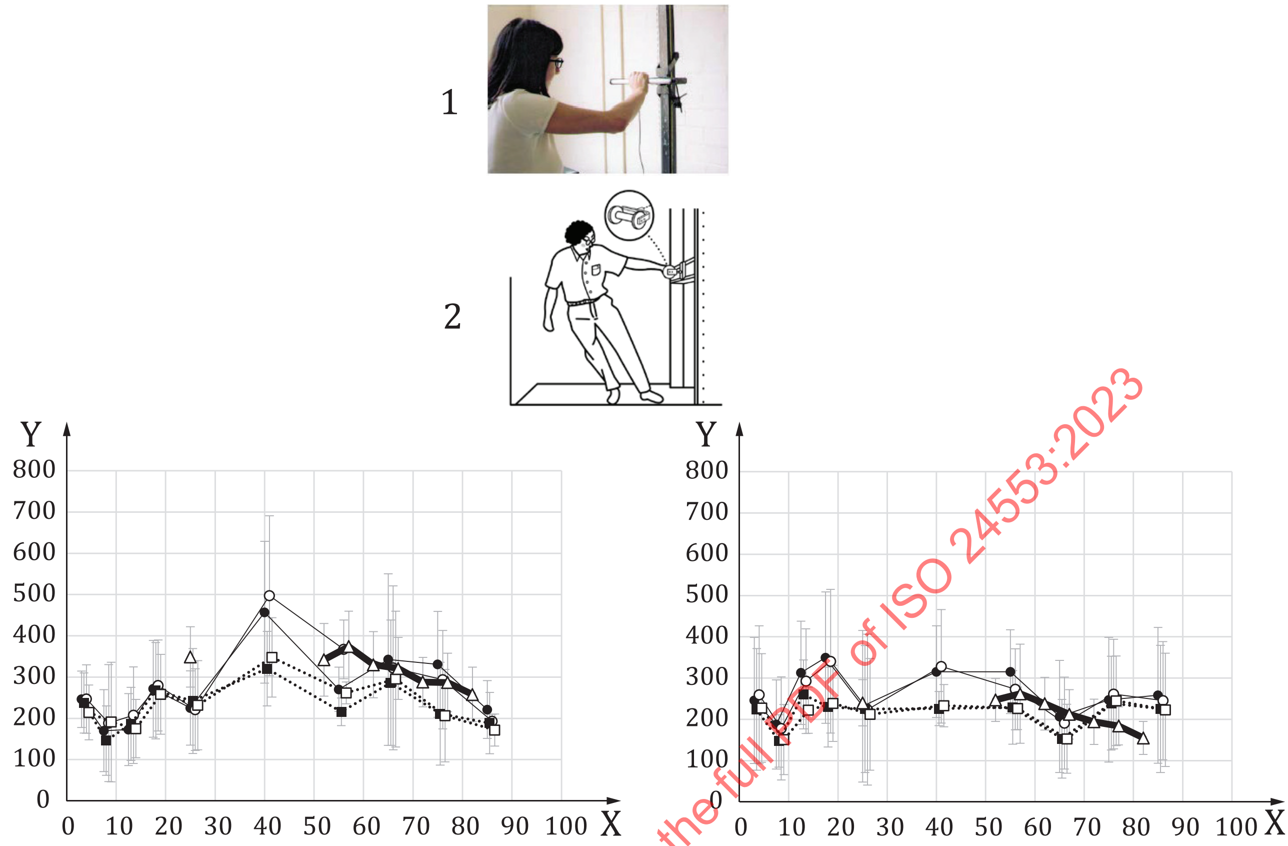
SOURCE References [8] and [14].

Figure B.3 — Maximum lifting strength with two hands for different gripping types and heights (50th percentile data of male and female subjects)

B.3.4 Maximum pushing or pulling strength with one hand

Data for maximum pushing or pulling strength with one hand as a function of age for male and female subjects are shown in Figure B.4. Data were obtained by DTI[20] and by TU Delft[21] using similar methods. The Delft data are only available for pulling. The DTI data were taken from a total of 154 persons (71 male and 83 female) of different age groups from 2 years to 90 years; the Delft data were from 750 persons (360 male, 390 female) from 20 years to over 80 years. The strength was exerted for a few seconds in a free-standing position, as shown in the inset, and the maximum strength was measured. The TU Delft data are also cited in ISO/TR 22411.

The maximum pushing or pulling strength with one hand increases gradually with age until it comes to a gentle peak between 30 years and 50 years of age. It then decreases gradually with age for male and female subjects. Male strength is greater than female strength for both pushing and pulling, but no significant difference was found in people younger than 20 years old. Pushing strength is generally greater than pulling strength. No difference was found for the bar orientation, either horizontal or vertical.



a) Male **b) Female**

Key

X age (years)
Y pushing or pulling strength (N)
1 measuring method by DTI (pushing a horizontal bar)
2 measuring method by TU Delft (pulling a horizontal bar)

—●— pushing a vertical bar (DTI)
—○— pushing a horizontal bar (DTI)
···■··· pulling a vertical bar (DTI)
···□··· pulling a horizontal bar (DTI)
▬△▬ pulling a horizontal bar (TU Delft)

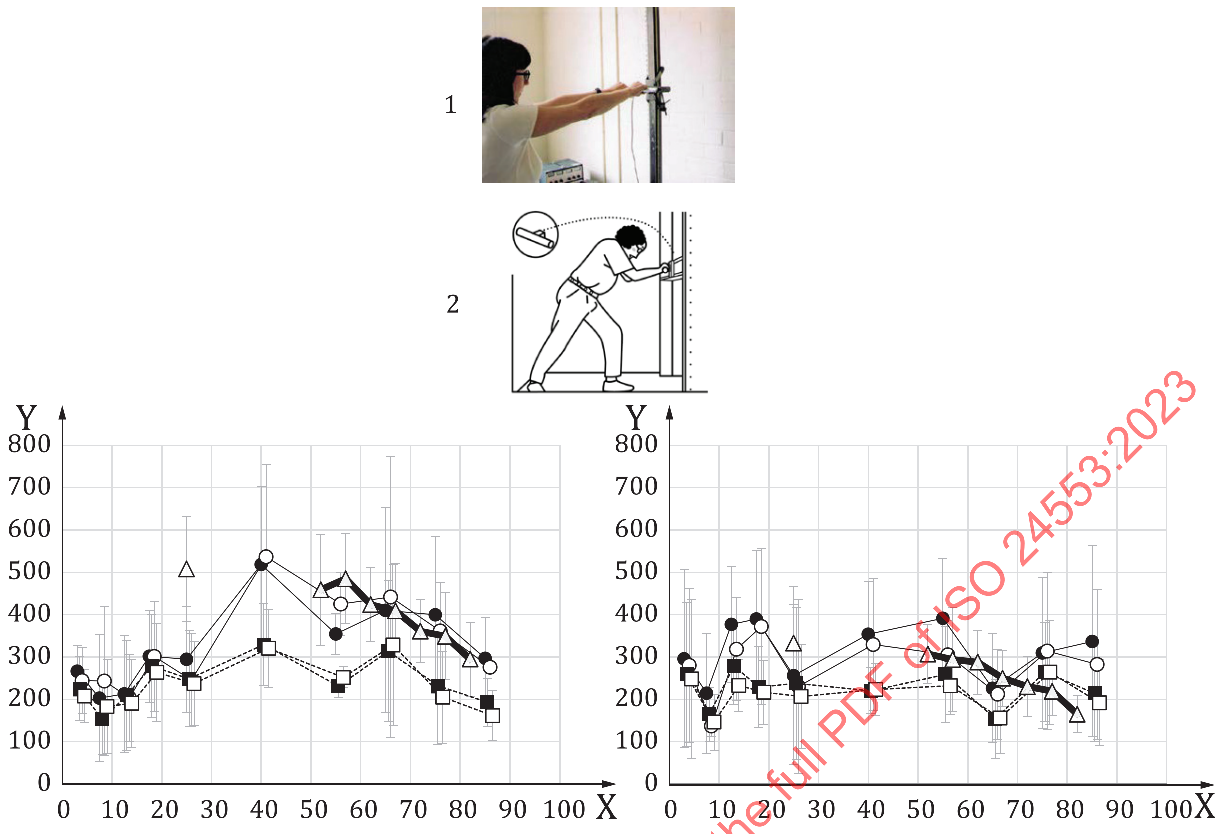
NOTE Vertical bars refer to standard deviations.

SOURCE References [8], [20] and [21].

Figure B.4 — Maximum pushing and pulling strength with one hand for male and female subjects of different ages

B.3.5 Maximum pushing or pulling strength with two hands

Figure B.5 presents the same data as Figure B.4 but with two hands.[20],[21] The Delft data are only available for pushing. Similar features to those obtained with one hand are found for two hands, except for the range in strength, which is larger with two hands than with one hand, as expected. The TU Delft data are also cited in ISO/TR 22411.



a) Male

b) Female

Key

X age (years)

Y pushing or pulling strength (N)

—●— pushing a vertical bar (DTI)

—○— pushing a horizontal bar (DTI)

···■··· pulling a vertical bar (DTI)

···□··· pulling a horizontal bar (DTI)

▬△▬ pushing a horizontal bar (TU Delft)

1 measuring method by DTI (pulling a horizontal bar)

2 measuring method by TU Delft (pushing a horizontal bar)

NOTE Vertical bars refer to standard deviations.

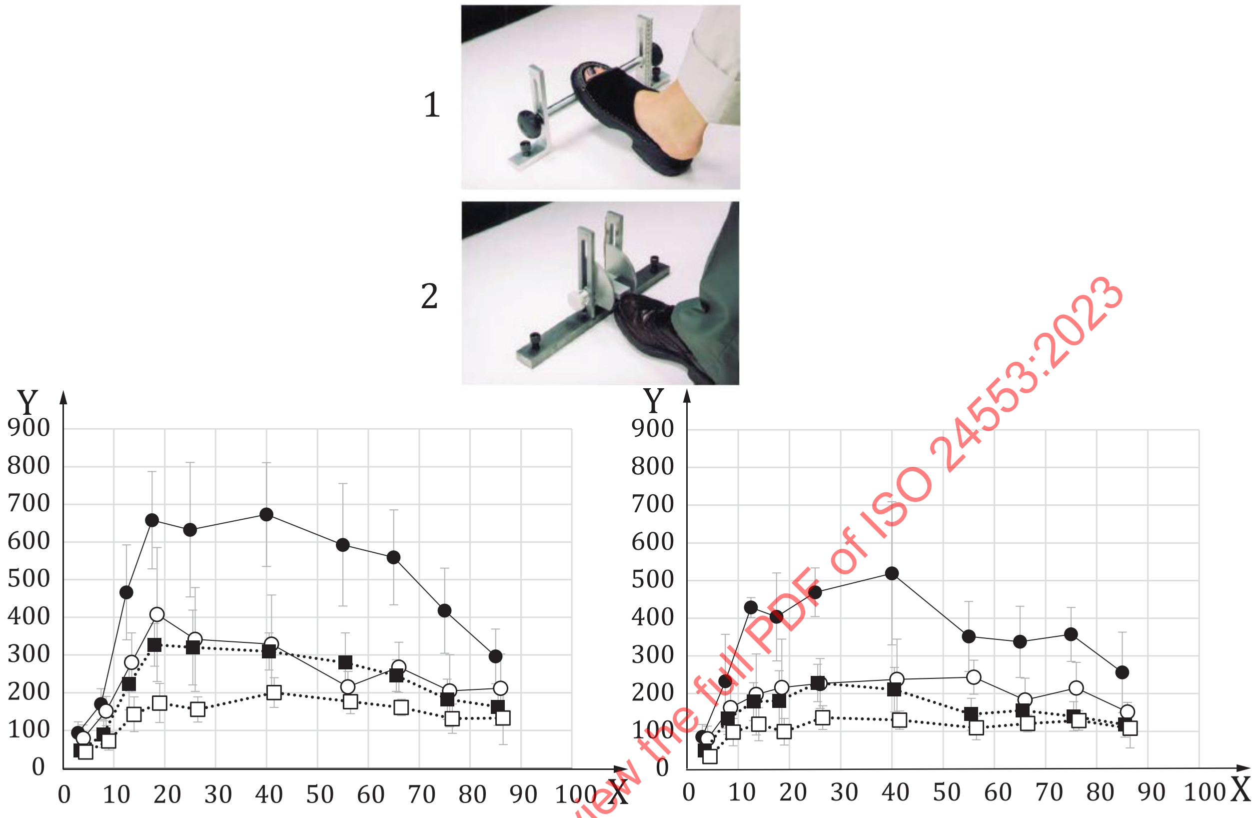
SOURCE References [8], [20] and [21].

Figure B.5 — Maximum pushing and pulling strength with two hands for male and female subjects of different ages

B.3.6 Maximum pressing and lifting strength with feet

Figure B.6 shows the maximum pressing and lifting strength with the foot measured by DTI.[20] The data were collected from a total of 140 persons (64 male and 76 female) of different age groups from 2 years to 90 years. A bar and a pedal were used for both pressing and lifting (see Figure B.6). Maximum pressing and lifting strengths with the foot were measured. Measurements were conducted of subjects in a standing posture.

For both pressing and lifting, male subjects exert higher strength than female subjects. The general trend of ageing effects observed for pushing or pressing with the hands was found here too, with a gradual increase with age up to a plateau at about 20 years to 50 years and a gradual decrease with age over 50 years. Pressing strength is considerably greater than that of lifting. Particularly, the pressing on a bar is much greater than the other conditions.



a) Male

b) Female

Key

X	age (years)	1	a bar (at pressing)
Y	pressing or lifting strength (N)	2	a pedal (at lifting)
—●—	pressing a bar		
—○—	lifting a bar		
···■···	pressing a pedal		
···□···	lifting a pedal		

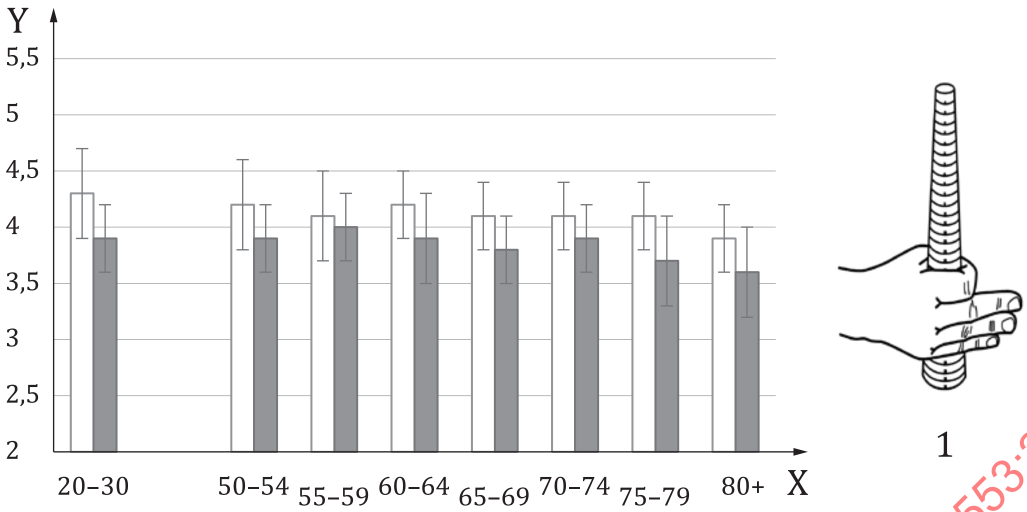
NOTE Vertical bars refer to standard deviations.

SOURCE Reference [20].

Figure B.6 — Maximum pressing and lifting strength with feet for male and female subjects of different ages

B.3.7 Maximum grip diameter

Figure B.7 shows the maximum grip diameter of the hand measured at TU Delft.[21] Data were obtained from 750 persons (360 male, 390 female) of different age groups from 20 years to over 80 years by measuring the maximum diameter of the circle made with the thumb and the forefinger, as shown in the inset of Figure B.7. The diameter shows a gradual decrease with age, with larger diameter shown by male subjects than by female subjects. The data are also cited in ISO/TR 22411.



Key

X	age (years)
Y	grip diameter (cm)
☐	male subjects
■	female subjects
1	grip diameter and a measuring cone

NOTE Vertical bars refer to standard deviations.

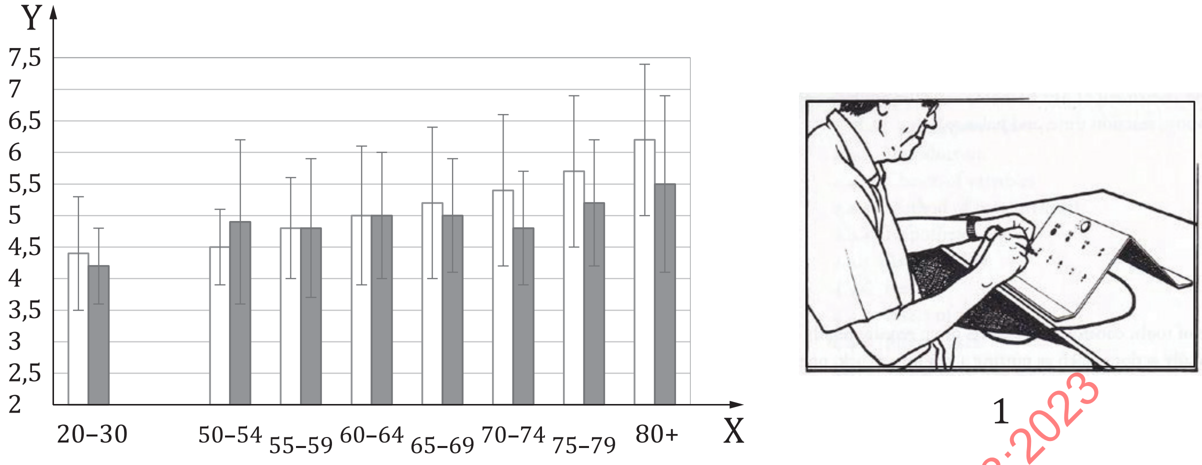
SOURCE References [8] and [21].

Figure B.7 — Grip diameter measured using a cone for male and female subjects of different ages

B.3.8 Dexterity: steadiness of hand–eye coordination

Figure B.8 shows ergonomics data concerned with dexterity. The dexterity was defined and measured as hand–eye coordination by TU Delft for 750 persons (360 male, 390 female) of different age groups from 20 years to over 80 years.[21] Measurements were conducted asking the subject to insert a needle (2 mm diameter) into holes of variable diameter without touching the hole edge. The minimum diameter at which the task was completed was measured.

The measured diameters were 4,4 mm to 6,2 mm for male subjects and 4,3 mm to 5,9 mm for female subjects, showing a gradual increase with age and indicating decreased dexterity with age. No significant difference was found between male and female subjects, but a slightly steeper age-related change was observed for male subjects. The data are also cited in ISO/TR 22411.



Key

X age (years)

Y diameter of a hole (mm)

□ male subjects

■ female subjects

1 measurement of hand–eye coordination steadiness

NOTE Vertical bars refer to standard deviations.

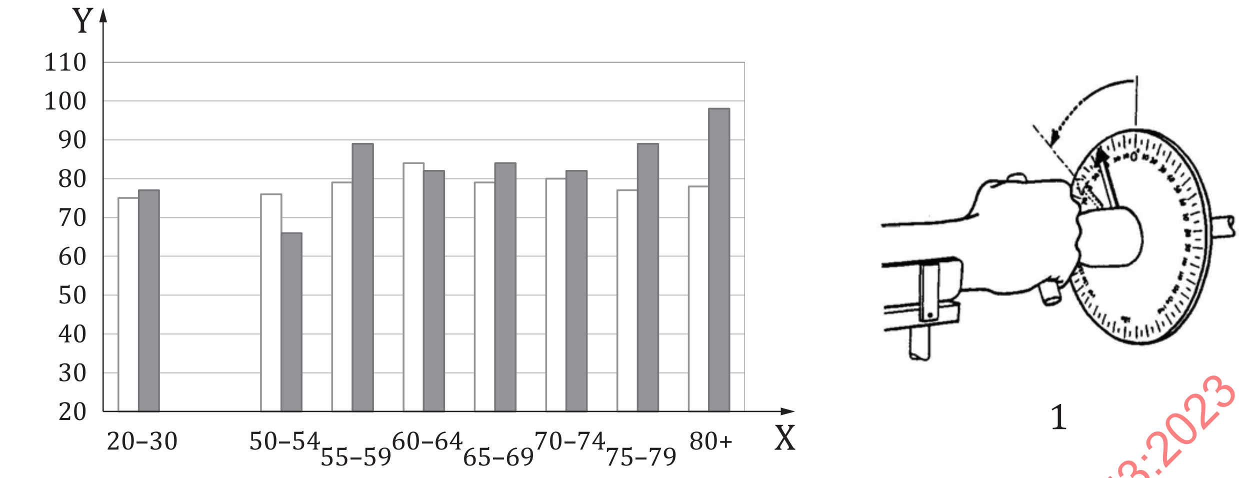
SOURCE References [8] and [21].

Figure B.8 — Steadiness of hand–eye coordination for male and female subjects of different ages

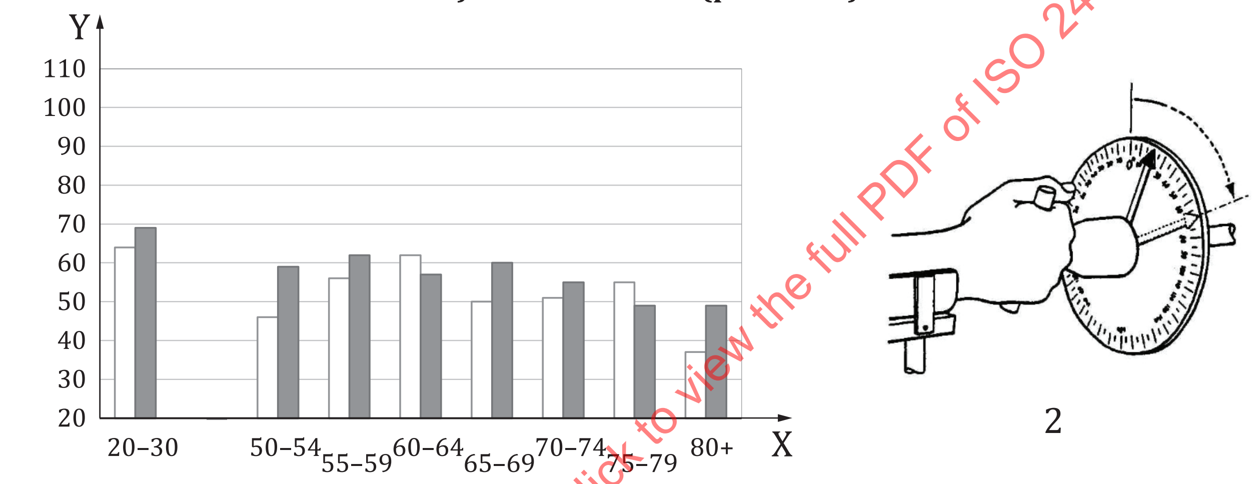
B.3.9 Maximum angle of the wrist for inward (pronation) and outward (supination) rotation for male and female subjects of different ages

Maximum angles of rotating the wrist inward (pronation) and outward (supination) are shown respectively in Figure B.9 a) and Figure B.9 b). Data were measured by TU Delft sampling from 750 persons (360 male, 390 female) of different age groups from 20 years to over 80 years.[21] The rotation angles were measured using a T-shaped handle without moving the lower arm as shown in the inset of the figure. The fifth percentile data are shown as a useful criterion for practical design so that most people can rotate the wrist within the value.

Data show that the female wrist is more flexible in rotation than the male wrist. Almost no ageing effect was observed for inward rotation (pronation), although slight reduction with age in the rotation angle was observed for outward rotation(supination) for both male and female subjects. The data are also cited in ISO/TR 22411.



a) Inward rotation (pronation)



b) Outward rotation (supination)

Key

X	age (years)	1	measurement of inward rotation (pronation)
Y	rotation angle of the wrist (degrees)	2	measurement of outward rotation (supination)
☐	male subjects		
■	female subjects		

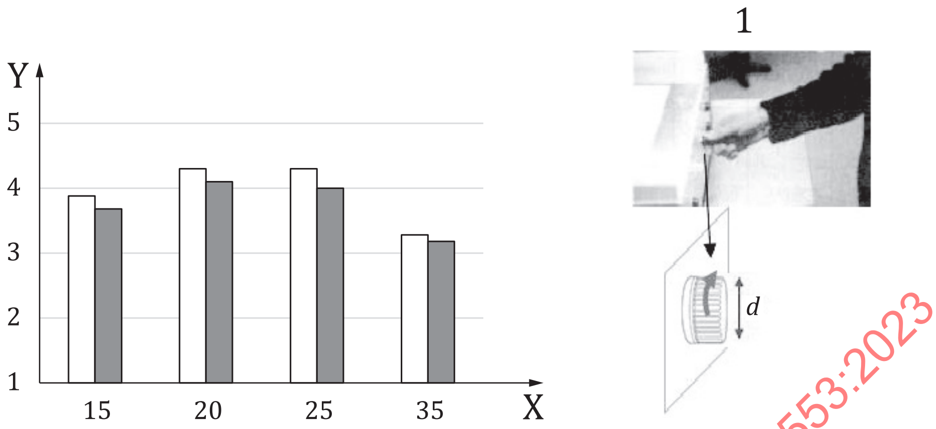
NOTE The data refer to the fifth percentiles.

SOURCE References [8] and [21].

Figure B.9 — Maximum angle of the wrist for inward and outward rotation for male and female subjects of different ages

B.3.10 Dial diameter for ease of rotation with fingers

Figure B.10 shows data for the circular dial diameter for easy rotation and adjustment with fingers measured by HQL.[18] Ease of operation was evaluated by 12 older subjects (two male and two female each in their 60s, 70s and 80s) and eight young subjects (two male and two female each in their 20s and 30s) using a five-point score (1, difficult; 2, slightly difficult; 3, moderate; 4, slightly easy; 5, easy) when the subject rotating a dial attached to a vertical plane (see the inset of the figure). Average evaluation scores are shown in the bar diagram of Figure B.10. The circular dial for easy operation is neither too small nor too large; the highest evaluation score was observed for the range of 20 mm to 25 mm diameter. A smaller dial was preferred by older subjects more than by young subjects. Variation of data is not available.



Key

X	dial diameter (mm)	1	circular dial on a vertical panel and operation
Y	ease of operation score (1: difficult to 5: easy)	*d*	diameter of the dial
☐	young subjects		
■	older subjects		

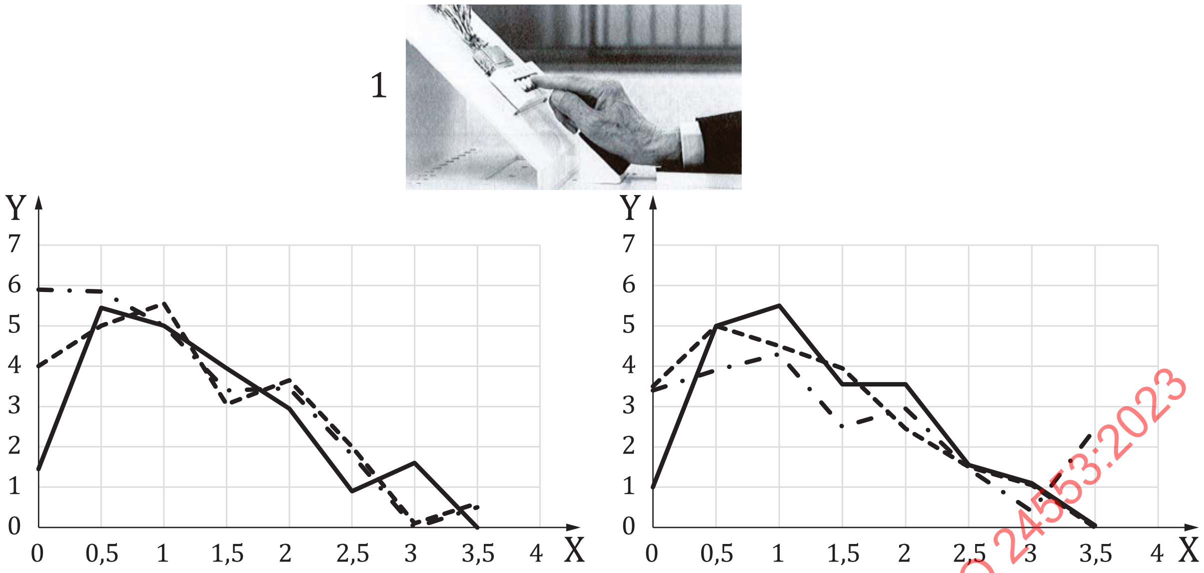
SOURCE Reference [18].

Figure B.10 — Subjective evaluation of diameter of a circular dial for ease of rotation with fingers for young (in their 20s and 30s) and older (in their 60s to 80s) subjects

B.3.11 Preferred stroke length for pushing a small button with the forefinger

Subjective preference data for the stroke length of a push-button when pushing the button with the forefinger are shown in Figure B.11 for young and older people, which were reported by Kikuchi et al.[22] The data were obtained from 24 young (20 years to 40 years old) and 32 older people (over 65 years old) who were asked to push an array of small (13 mm diameter) push-buttons with different strokes from 0 mm to 3,5 mm in 0,5 mm steps. Each subject reported a preference of the operation using a seven-point scale at three orientations of the board, i.e. a horizontal plane (downward pushing), an oblique-angle plane (45 ° pushing) and a vertical plane (forward pushing). See the inset of Figure B.11.

Stroke lengths of 0,5 mm to 1,0 mm were most preferred by both young and older people, but older people preferred a slightly longer stroke than younger people did. No significant difference was found among orientations of the operation board.



a) Young subjects **b) Older subjects**

Key

X push-button stroke length (mm)

Y preference score (1: least preferred; 7: most preferred)

——— downward pushing on a horizontal plane

------ oblique angle (45 °) pushing

— · — forwards pushing on a vertical plane

1 pushing a button with the forefinger (at oblique angle)

SOURCE Reference [22].

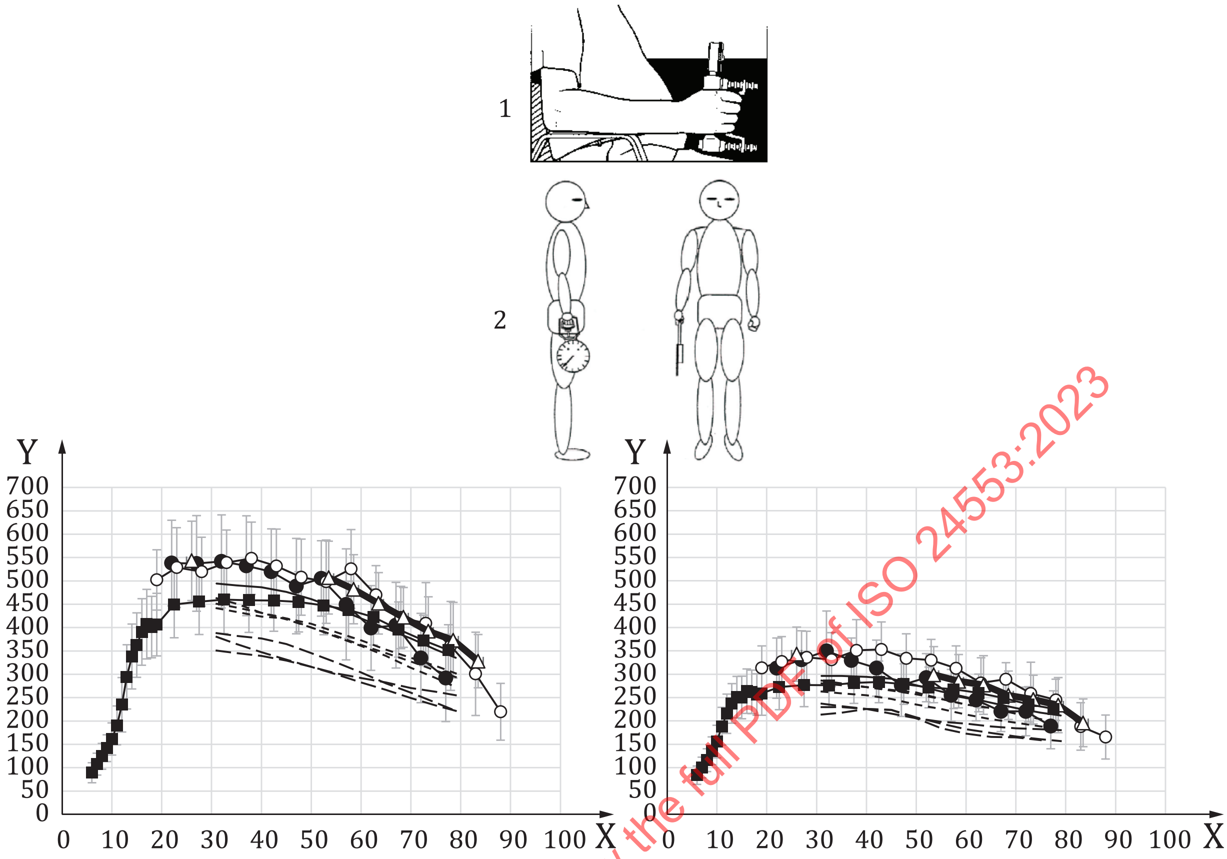
Figure B.11 — Preferred stroke length for pushing a button with the forefinger for young (20-year-old to 40-year-old) and older (over 65-year-old) subjects

B.3.12 Maximum grip strength (of one hand)

Figure B.12 shows data for maximum grip strength of one hand measured from five studies conducted in different countries. Data of Mathiowetz et al.[23] were sampled from 310 male and 328 female subjects aged from 20 years to 94 years. Data of Angst et al.[24] were from 496 male and 482 female subjects aged from 18 years to 96 years. Data of TU Delft[21] were from 360 male and 390 female subjects aged from 20 years to over 80 years. Data of MEXT[26] were from 31 637 male and 30 606 female subjects aged from 6 years to 79 years. Data of Leong et al.[25] were from 52 059 male and 73 403 female subjects aged from 35 years to 70 years collected from 21 countries and classified into seven regions. All data were measured using conventional hand grip strength meters (Jamar dynamometer for Mathiowetz et al., Angst et al., TU Delft and Leong et al. and the Smedley dynamometer for MEXT). See the inset of Figure B.12.

Similar results were obtained for these data sets, whereas some regional data of Leong et al. (Africa, South-Ease Asia, South Asia) and Japanese data showed slightly lower strength than that of groups measured in Europe and North America (Angst et al., Mathiowetz et al. and Leong et al.).

The maximum grip strength increases rapidly from the age of 6 years to about 20 years, until it reaches a plateau, maintaining an almost constant level up to about 60 years. It then decreases gradually after the age of 60. This trend is the same for male and female subjects but the average strength of female subjects is about two-thirds of that of male subjects, except during childhood, for which no significant difference was found. The TU Delft data and the MEXT data are also cited in ISO/TR 22411.



a) Male **b) Female**

Key

X	age (years)	1	measuring method for Mathiowetz et al. (A), Angst et al. (B), TU Delft (C) and Leong et al. (E,F,G)
Y	grip strength (N)	2	measuring method for MEXT (D)
—●—	Mathiowetz et al.		
—○—	Angst et al.		
▬△▬	TU Delft		
···■···	MEXT		
———	Leong et al. (Europe and North America)		
- - - -	Leong et al. (three data sets of South America, the Middle East and China, respectively)		
— —	Leong et al. (three data sets of Africa, Southeast Asia and South Asia, respectively)		

NOTE Vertical bars refer to standard deviations.

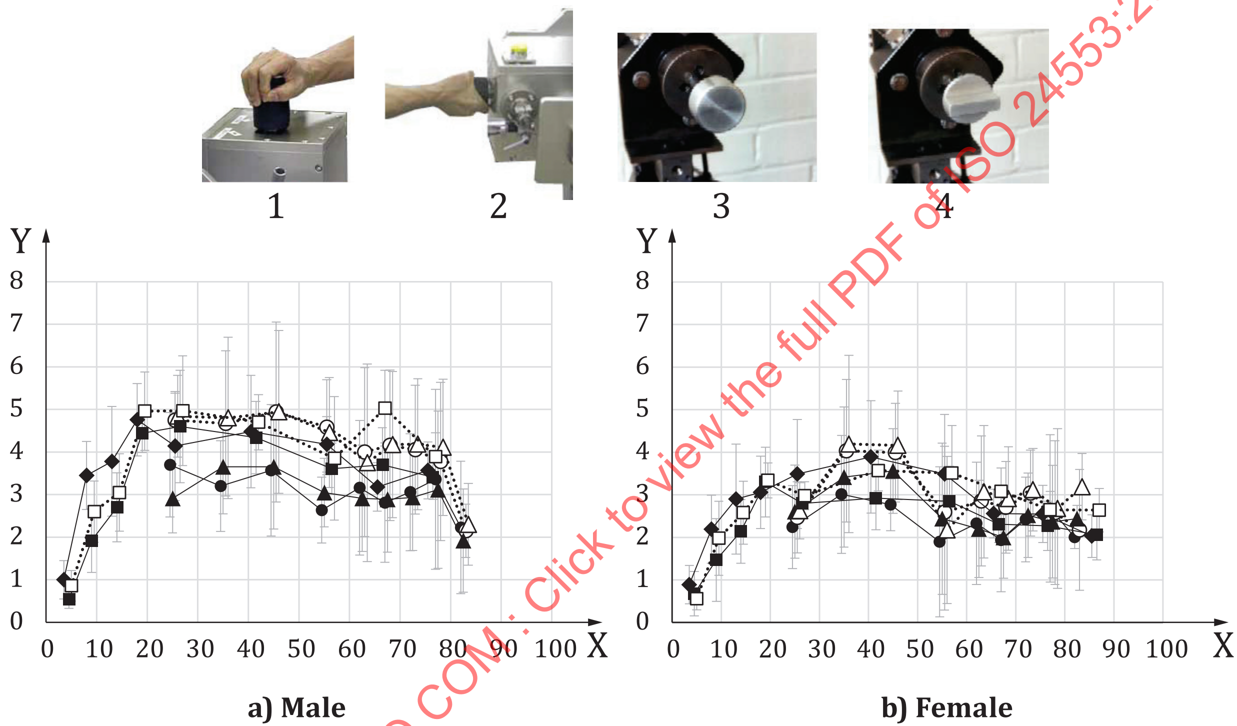
SOURCE References [8], [21] and [23] to [26].

Figure B.12 — Maximum grip strength of one hand for male and female subjects of different ages

B.3.13 Maximum twisting strength of the wrist

Maximum twisting strengths of the wrist measured for different experiment contexts are shown in Figure B.13 for male and female subjects of different age groups. The data were provided by NITE[27] and DTI.[19] The NITE data were sampled from 204 to 210 male subjects and 138 to 142 female subjects (depending on the experiment context) whose ages were 20 years to over 80 years, and the DTI data from 64 male and 86 female subjects of 2 years to 90 years. Both measurements employed the height at elbow when standing. Subjects were asked to turn a circular knob oriented vertically or horizontally with maximum effort for a few seconds. The NITE study used a 50 mm diameter knob grasped by the fingers and the palm. The DTI study used a 40 mm diameter knob grasped only by the fingers. See inset of Figure B.13.

The measured twisting torques were 3 Nm to 5 Nm for male subjects and 2 Nm to 4 Nm for female subjects in adulthood, depending on the knob type and orientation. The torque increases with age from 2 years to 20 years until it almost reaches a plateau, which remains until around 60 years to 70 years; it then decreases with age. No significant difference was found between inward rotation (supination) and outward rotation (pronation), whereas the vertical orientation yields a slightly higher strength than the horizontal orientation of the knob in the NITE data.



Key

X age (years)

Y twisting torque (Nm)

—●— circular knob, 50 mm diameter, outward rotation, vertical orientation; NITE

····○···· circular knob, 50 mm diameter, outward rotation, horizontal orientation; NITE

—▲— circular knob, 50 mm diameter, inward rotation, vertical orientation; NITE

····△···· circular knob, 50 mm diameter, inward rotation, horizontal orientation; NITE

—◆— circular knob, 40 mm diameter, clockwise rotation, vertical orientation; DTI

—■— ridged knob, clockwise rotation, vertical orientation; DTI

····□···· ridged knob, clockwise rotation, horizontal orientation, DTI

1 circular knob used in the NITE measurement, vertical orientation

2 circular knob used in the NITE measurement, horizontal orientation

3 circular knob used in the DTI measurement, horizontal orientation

4 ridged knob used in the DTI measurement, horizontal orientation

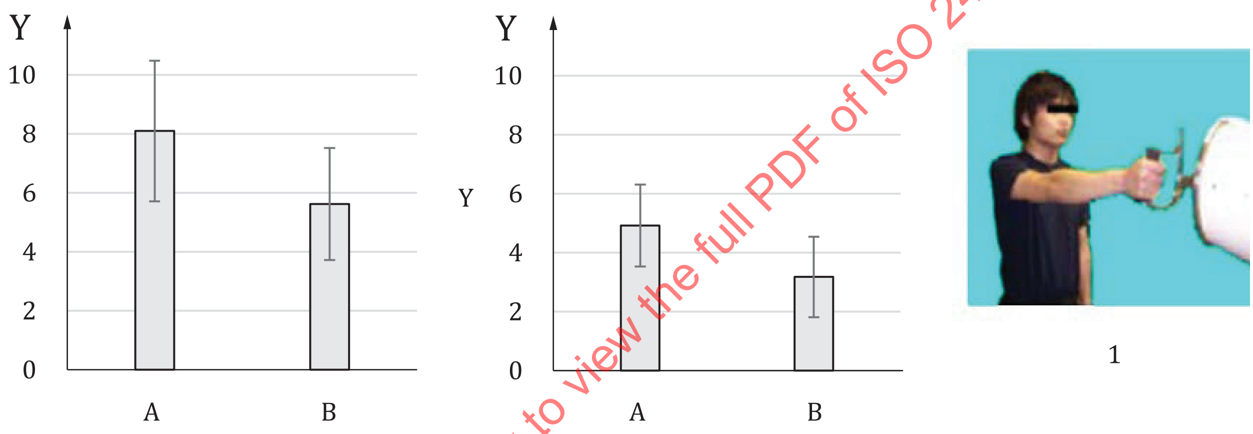
NOTE Vertical bars refer to standard deviations.

SOURCE References [19] and [27].

Figure B.13 — Maximum twisting strength of the wrist for male and female subjects of different ages

B.3.14 Maximum twisting strength of the upper limbs

Figure B.14 shows the maximum torque strength for twisting the upper limb provided by NITE.[27] Data were obtained from 80 persons (38 male and 42 female) aged from 60 years to 73 years (65,3 and 64,9 averaged years for male and female subjects, respectively). The twisting torque was measured using a rotary handle set in a horizontal orientation as shown in the inset of the figure. Each subject was asked to use the right hand, to grip and to rotate the handle inwards (pronation) or outwards (supination) with the upper limb with the maximum effort. Measurements were taken at the height of the shoulder when standing. The maximum torque of male subjects was greater than that of female subjects. The torque for pronation was significantly greater than that for supination.



a) Male

b) Female

Key

Y twisting torque (Nm)

A pronation (anticlockwise by right hand)

B supination (clockwise by right hand)

1 method for measurement

NOTE Vertical bars refer to standard deviations.

SOURCE Reference [27].

Figure B.14 — Maximum twisting strength of the upper limbs for older (60-year-old to 73-year-old) male and female subjects

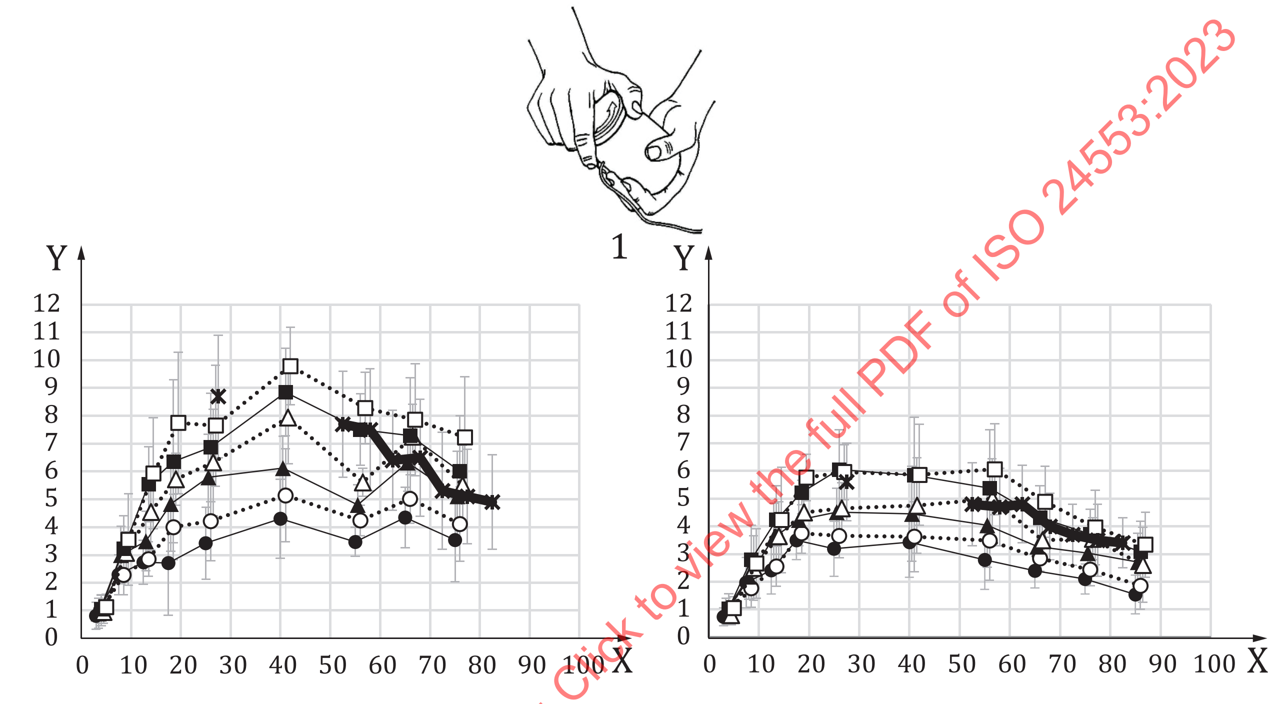
B.3.15 Maximum jar-opening strength of two hands

The maximum jar-opening strength when a person opens a jar lid has been provided by DTI [19] and TU Delft[21] for male and female subjects of different age groups. Figure B.15 shows the data as a function of age for different jar and lid diameters. The DTI data were those of 144 persons (59 male and 85 female) aged from 2 years to 90 years. The TU Delft data were of 750 persons (360 male and 390 female) aged from 20 years to over 80 years.

Each subject was asked to hold a jar with a measuring device and to try to open a lid with two hands (the lid does not open) in a standing posture, and to exert maximum twisting strength for a few seconds.

The jar and lid had different diameters: 45 mm, 65 mm and 85 mm with smoothed and knurled lids for the DTI measurements and 66 mm with a smoothed lid for the TU Delft measurements.

The opening strength measured ranged in torque from 3 Nm to 10 Nm for male adults and from 2 Nm to 6 Nm for female adults, depending on the jar diameter and the lid type. The torque increases with age from 2 years to 20 years until it almost reaches a plateau, which remains until about 60 years to 70 years before decreasing with age. This general trend shows the effects of ageing on human strength. A significant effect of the jar diameter was found: the larger the diameter, the more strength exerted. The knurled lid exerted a larger strength than the smoothed lid. The TU Delft data are also cited in ISO/TR 22411.



a) Male

b) Female

Key

X	age (years)	1	measuring method and a device
Y	twisting torque (Nm)		
—●—	45 mm diameter, smooth lid (DTI)		
···○···	45 mm diameter, knurled lid (DTI)		
—▲—	65 mm diameter, smooth lid (DTI)		
···△···	65 mm diameter, knurled lid (DTI)		
—■—	85 mm diameter, smooth lid (DTI)		
···□···	85 mm diameter, knurled lid (DTI)		
━✱━	66 mm diameter, smooth lid (TU Delft)		

NOTE Vertical bars refer to standard deviations.

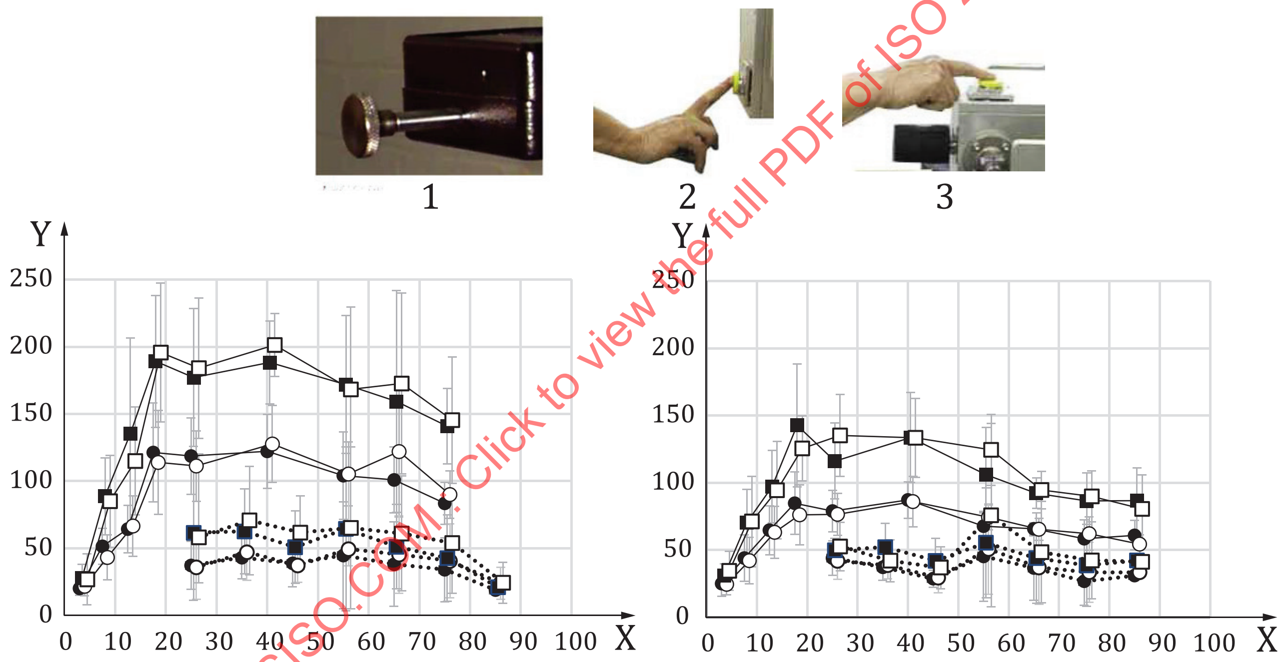
SOURCE References [8], [19] and [21].

Figure B.15 — Maximum jar-opening strength with two hands for male and female subjects of different ages

B.3.16 Maximum pushing strength with a finger

Figure B.16 shows data for maximum pushing strength with a finger measured at DTI[19] and NITE[27]. Both data employed forward and downward pushing with the forefinger and the thumb. DTI used a circular force place and NITE used an apparatus simulating an ordinary push-button. See the inset figures in Figure B.16. The DTI data were sampled from 148 persons (65 male and 83 female) ranging in age from 2 years to 90 years, and the NITE data from 329 persons (194 male and 135 female) from 21 years to over 80 years.

A typical ageing effect was observed for both the DTI and the NITE data: a steep increase up to 20 years of age then reaching an almost constant level up to 60 years of age followed by a gradual decrease with age after that. Sex differences were also observed. No large difference was found between forward and downward pushing, but a significant difference was found between the forefinger and the thumb: the thumb yields greater strength than the forefinger. Large differences can be found between the DTI and the NITE data, perhaps because of the different methods employed in their measurements. The force plate used for the ergonomic measurements by DTI generates a greater force than the ordinary push-button. The NITE data are also cited in ISO/TR 22411.



a) Male

b) Female

Key

X age (years)

Y pushing strength (N)

—●— forefinger, forward (DTI)

—○— forefinger, downward (DTI)

—■— thumb, forward (DTI)

—□— thumb, downward (DTI)

···●··· forefinger, forward (NITE)

···○··· forefinger, downward (NITE)

···■··· thumb, forward (NITE)

···□··· thumb, downward (NITE)

1 force plate to measure pushing strength (DTI)

2 push-button for measuring pushing strength forward (NITE)

3 push-button for measuring pushing strength downward (NITE)

NOTE Vertical bars refer to standard deviations.

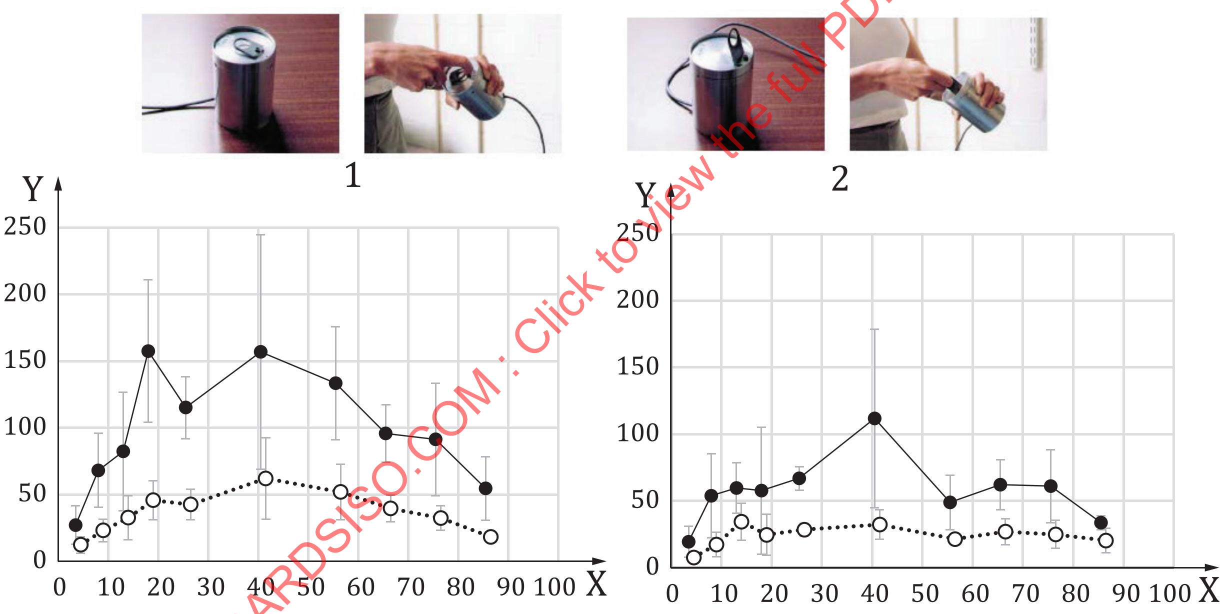
SOURCE References [19] and [27].

Figure B.16 — Maximum pushing strength with the forefinger and thumb for male and female subjects of different ages

B.3.17 Maximum pulling strength on a can ring pull

Maximum pulling strength on a can ring pull with the hand and the forefinger was measured by DTI,[20] the data of which are shown in Figure B.17. The measurements were carried out with a can (100 mm height and 75 mm diameter) that had a ring pull (35 mm long and 23 mm diameter) on the top. The ring pull was in two positions: one at the starting position with a 5 mm space between the ring and the top surface (horizontal position), and the other one at 75 ° to the top of the can (vertical case). See the inset of Figure B.17. For each case, the subject was asked to pull the ring pull with the forefinger (the ring pull does not move) holding the can by the hand. The maximum strength was measured for 139 persons (60 male and 79 female) of different age groups from 2 years to 90 years.

The pulling strengths were in the range of 50 N to 150 N for male adults and 30 N to 100 N for female adults. General ageing effects were observed for both male and female subjects: a steep increase by 20 years of age, reaching a constant level up to 60 years of age, followed by a gradual decrease with age after that. The vertical case yields a significantly greater strength than the horizontal case.



a) Male **b) Female**

Key

X age (years)

Y pulling strength (N)

—●— vertical ring pull

—○— horizontal ring pull

1 horizontal ring pull

2 vertical ring pull

NOTE Vertical bars refer to standard deviations.

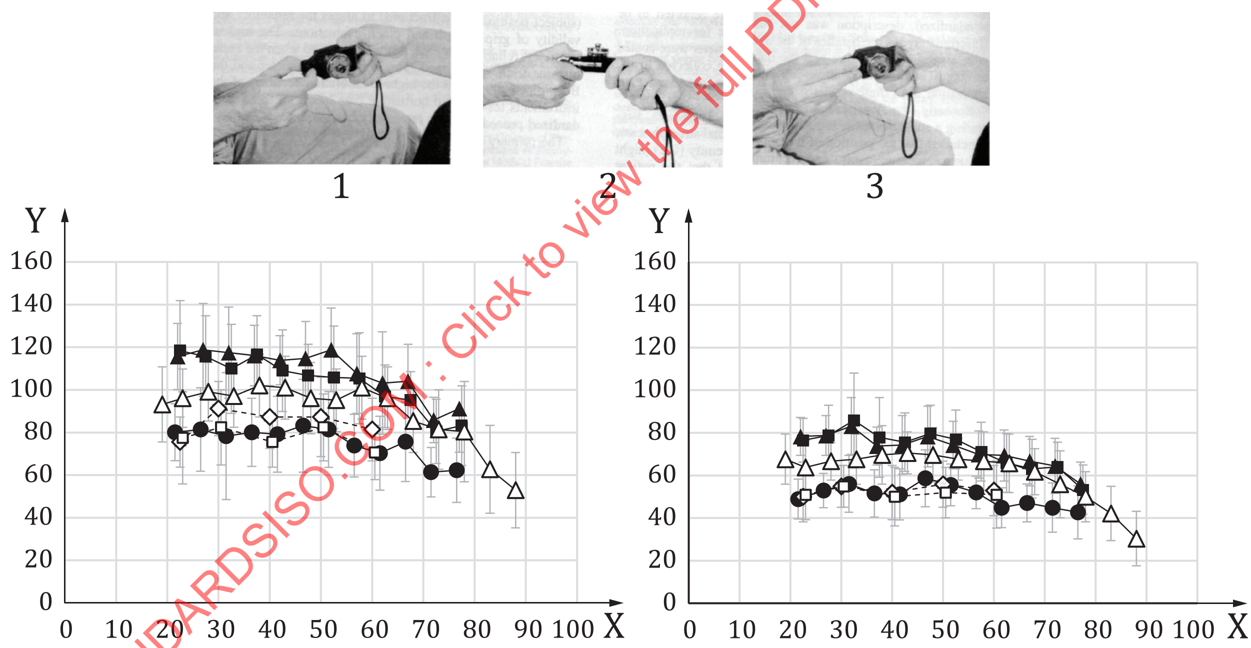
SOURCE Reference [20].

Figure B.17 — Maximum pulling strength with the hand and the forefinger on a can ring pull for male and female subjects of different ages

B.3.18 Maximum pinching strength with fingers (tip-pinch, key-pinch, palmar-pinch)

Figure B.18 shows the maximum pinch strength for pinching of three types: tip pinch, key pinch and palmar pinch (three-finger pulp pinch).[23],[24],[28] The Mathiowetz et al. data were obtained from 638 persons (310 male and 328 female) ranging in age from 20 years to 94 years,[23] the Angst et al. data (key pinch only) from 978 persons (482 male and 496 female) from 18 years to 96 years,[24] and the Lo et al. data (key pinch and palmar pinch only) from 198 persons (99 male and 99 female) from 20 years to 64 years, the former two trying to establish standard data for clinical use and the latter one for job design in manufacturing industries.

The data show almost constant values for the age range from 20 years to 60 years and a gradual decline with age after 60 years. The strength is from about 80 N to 120 N for male subjects and about 50 N to 80 N for female subjects. Tip pinch showed the lowest strength among the three pinch types. The strength of female subjects is about two-thirds of that of the male subjects throughout the life span measured.



a) Male

b) Female

Key

X age (years)

Y pinch strength (N)

—●— tip pinch (Mathiowetz, et al.)

—▲— key pinch (Mathiowetz, et al.)

—■— palmar pinch (three-finger pulp pinch) (Mathiowetz, et al.)

—△— key pinch (Angst et al.)

--◇-- key pinch (Lo et al.)

--□-- palmar pinch (Lo et al.)

1 tip pinch and a measuring device (Mathiowetz et al.)

2 key pinch and a measuring device (Mathiowetz et al.)

3 palmar pinch and a measuring device (Mathiowetz et al.)

NOTE Vertical bars refer to standard deviations.

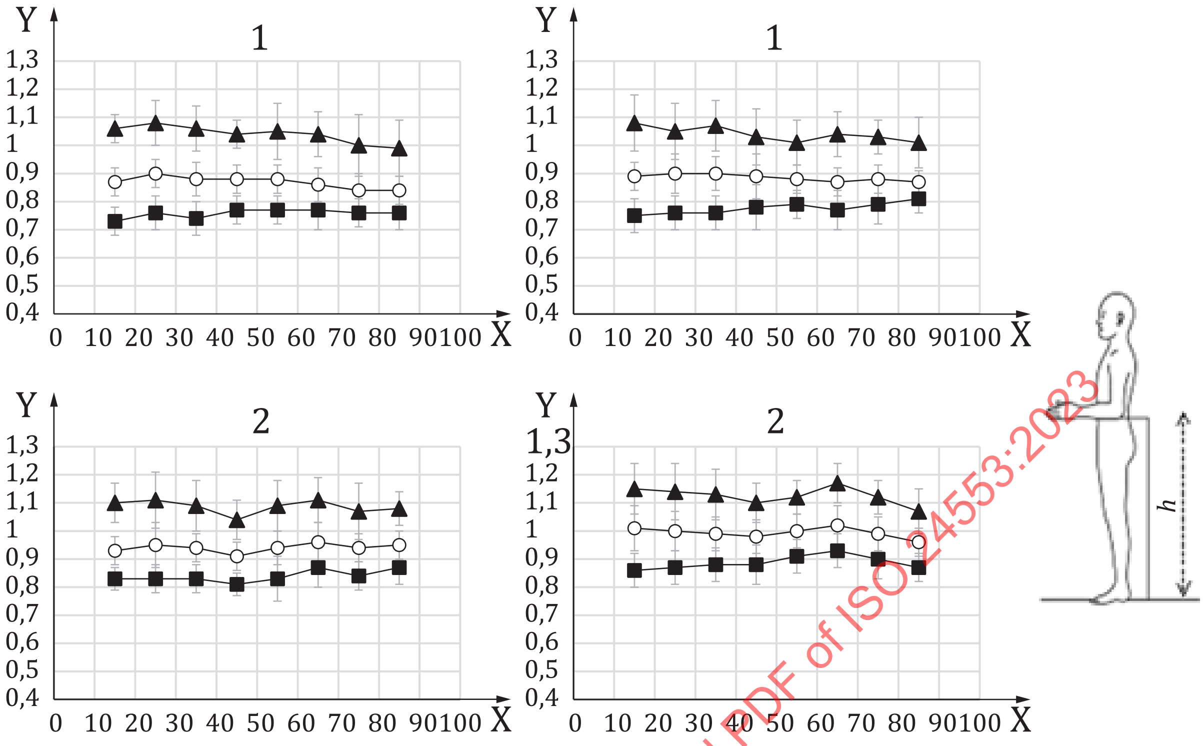
SOURCE References [23], [24] and [28].

Figure B.18 — Maximum pinching strength with fingers for male and female subjects of different ages

B.3.19 Appropriate height for pushing a button placed on a horizontal plane

Figure B.19 shows the acceptable height for pushing a button placed on a horizontal plane. Data were obtained by HQL from a total of 533 persons (259 male, 274 female) ranging in age from 16 years to over 80 years.[18] The subjects were asked to evaluate the ease of operation using a five-point scale for each of the pre-set heights of a working plane on which the button was placed. This evaluation was conducted both when standing and sitting. From these data, the upper acceptable limit height, comfort height and lower acceptable limit height were derived. Data in Figure B.19 are expressed as the relative height to the olecranon (lowest elbow point = 1,0) to compensate for differences in stature among subjects.

The data indicate that most people prefer the height of about 90 % of the height of olecranon as their comfort height, except for female subjects when sitting, for whom the height at olecranon is preferred. The acceptable range, i.e. between the upper and the lower acceptable limits, decreases with age for both male and female subjects.



a) Male

b) Female

Key

X	age (years)	1	standing
Y	height from the floor (relative to the olecranon height, *h*)	2	sitting
—▲—	upper limit acceptable	*h*	height of olecranon (Y = 1,00)
—○—	comfort		
—■—	lower limit acceptable		

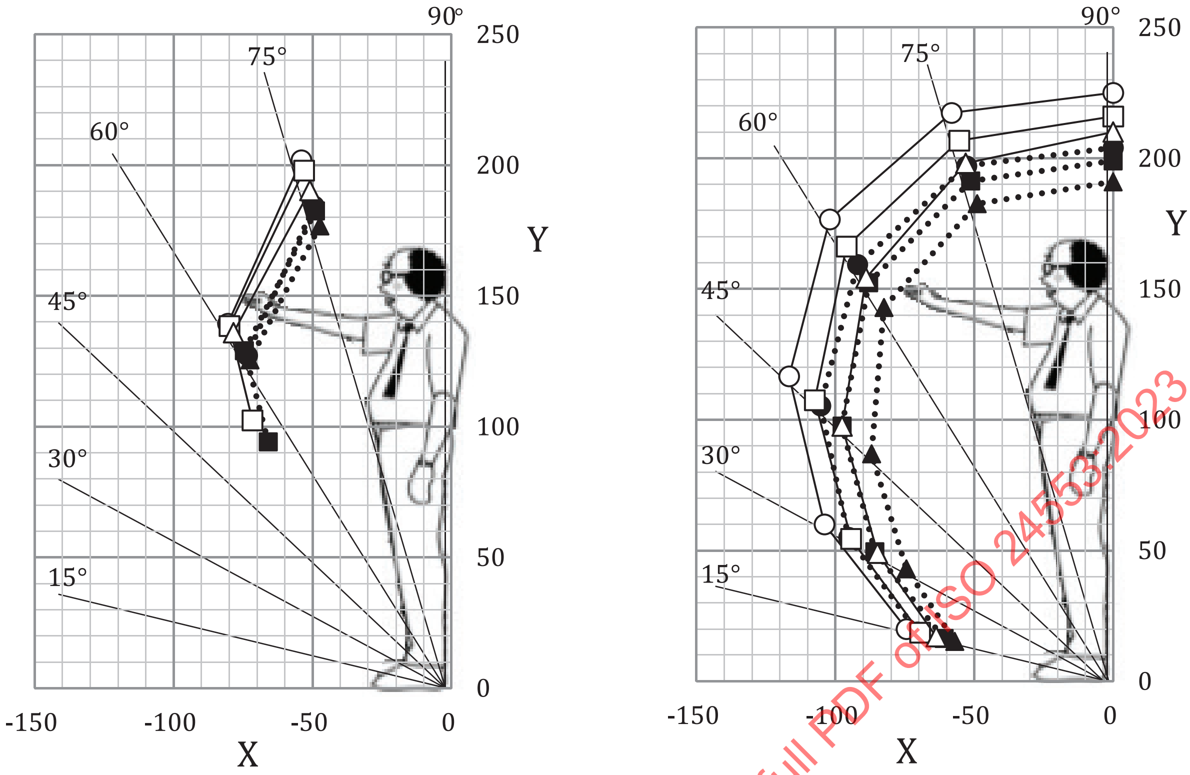
SOURCE Reference [18].

Figure B.19 — Height of an operation plane for pushing a button for male and female subjects of different ages

B.3.20 Vertical reach range of the upper limbs for simple touching while standing

Figure B.20 shows vertical reach range of the upper limb (right hand) in a standing posture measured at TU Delft.[21] Data were obtained from 750 persons (360 male, 390 female) of different ages and statures. Each subject was asked to stand upright and to mark the trace of the right-hand reach on the vertical panel at the right side with comfort reach and maximum reach. The comfort reach is the reach without bending the body forward; the maximum reach is the reach with bending the trunk while keeping the legs stretched. The data are classified into six groups of three different ages (young, old and older) and two different statures (smaller and taller). The mean values of the respective groups are shown in the figure.

Vertical reach range becomes smaller with increasing age and shorter stature. The data are also cited in ISO/TR 22411.



a) Comfort reach range   b) Maximum reach range

Key

X	horizontal distance (cm)
Y	vertical distance (cm)
—○—	age 20 years to 30 years, stature greater than or equal to 175 cm
···●···	age 20 years to 30 years, stature smaller than 175 cm
—□—	age 50 years to 74 years, stature greater than or equal to170 cm
···■···	age 50 years to 74 years, stature smaller than 170 cm
—△—	age over 75 years, stature greater than or equal to 165 cm
···▲···	age over 75 years, stature smaller than 165 cm

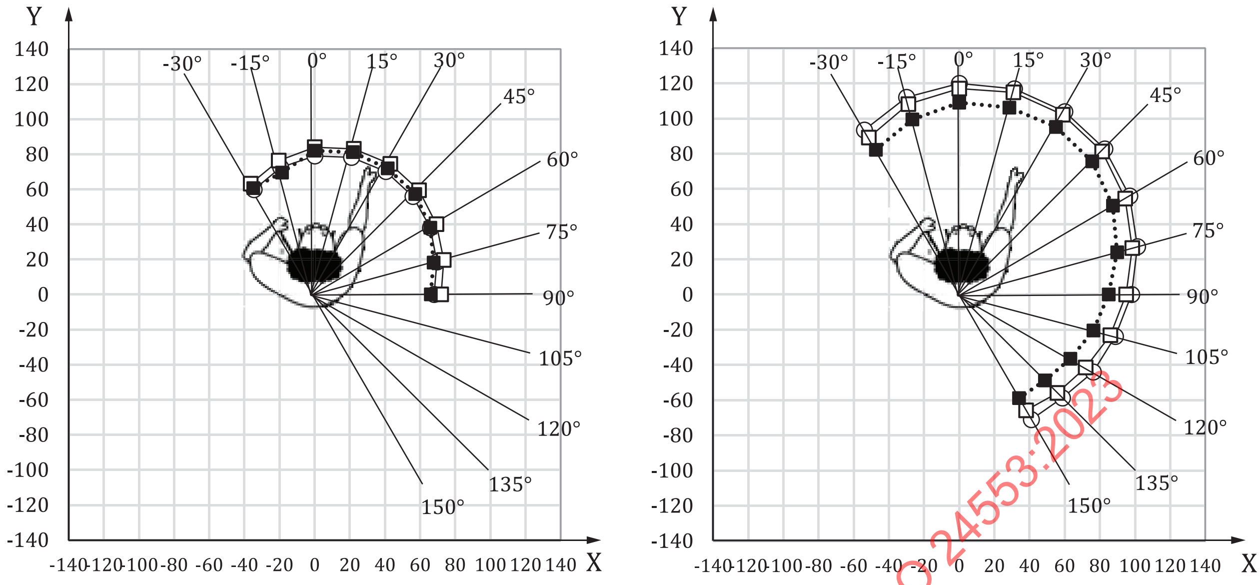
SOURCE References [8] and [21].

Figure B.20 — Vertical reach range while standing for persons of different ages and statures

B.3.21 Horizontal reach range of the upper limbs for simple touching while sitting

Figure B.21 presents the same data but for the horizontal reach range while sitting.[21] The subject was asked to mark the trace of the right-hand reach at the height of the elbow with comfort reach and maximum reach. The comfort reach represents reach without bending the trunk, while maximum reach is reach with bending the trunk. The data, measured from 760 samples, are classified into three groups of people of different ages and statures. The mean values of the respective groups are shown in the figure.

Horizontal reach range becomes smaller with increasing age and shorter stature, similar to the results obtained for the vertical range. The data are also cited in ISO/TR 22411.



a) Comfort reach range

b) Maximum reach range

Key

X	right–left distance (cm)
Y	forward–backward distance (cm)
—o—	age 20 years to 30 years
—□—	age over 50 years, stature greater than or equal to 170 cm
··■··	age over 50 years, stature smaller than 170 cm

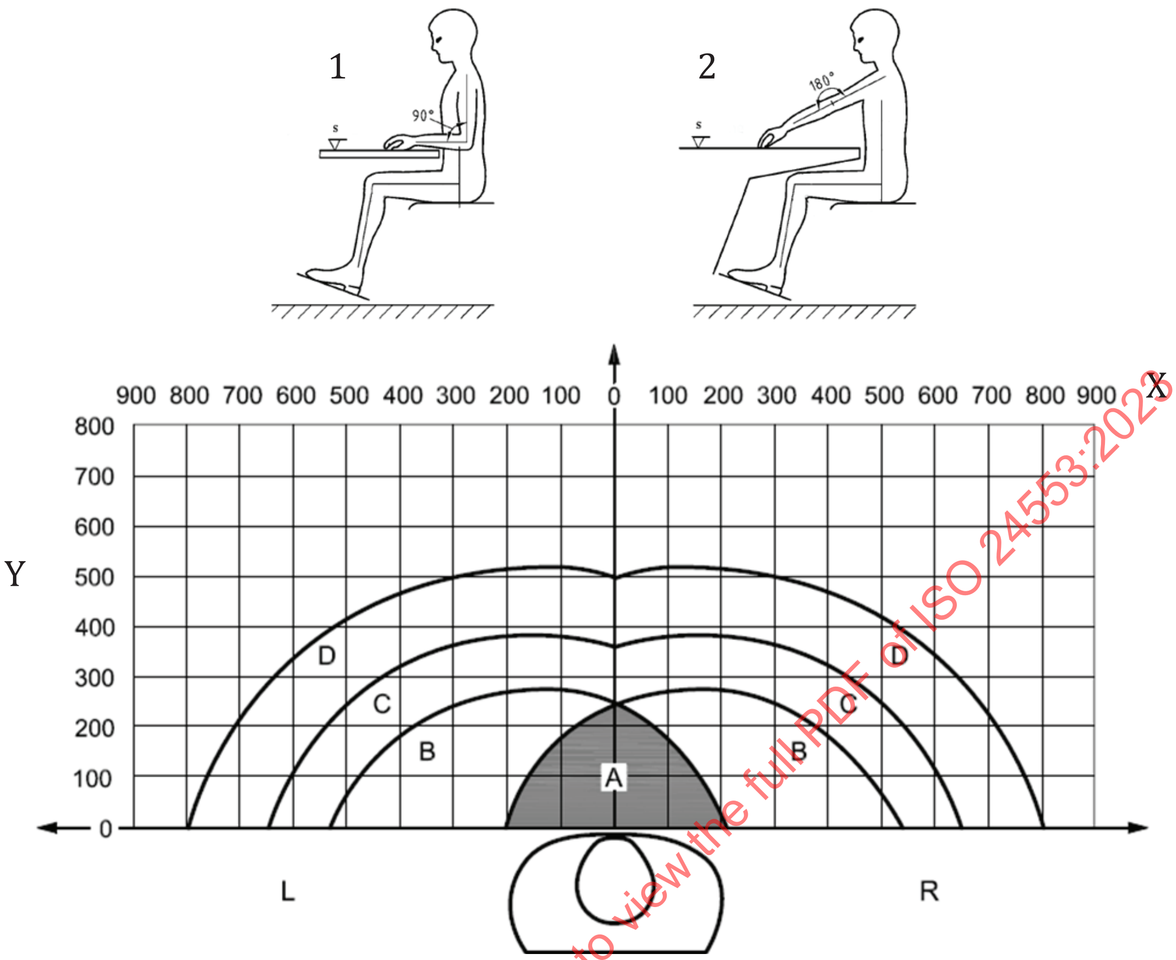
SOURCE References [8] and [21].

Figure B.21 — Horizontal reach range while sitting for persons of different ages and statures

B.3.22 Reach range of the upper limbs for grasping

Figure B.22 shows the horizontal reach range of the upper limb for grasping provided by DIN/Technical Report 124. Data were sampled only from female subjects of the fifth percentile of the German female body size (i.e. the smallest group). Measurements were conducted on a desk surface at a height of 750 mm with two postures, stretched and bent arm postures, as shown in the inset of the figure.

The optimum grasping area is the range that one can reach in the upright posture with bent arm and elbow joint at 90° (data A and B and posture 1). The functional grasping area is the range that one can reach in the upright posture with stretched arm and elbow joint at 180° (data C and posture 2). The extended grasping area is the range that is reachable with bending of the upper body (data D). Data are also cited in ISO/TR 22411.



Key

X right-left distance (mm)

Y forward distance (mm)

A optimum grasping area for both hands (envelope curves)

B optimum grasping areas (envelope curves)

C functional grasping areas (envelope curves)

D extended grasping areas (envelope curves)

1 upright seating posture with bent arm, e.g. elbow joint 90°

2 upright seating posture with stretched arm, e.g. elbow joint 180°

L left hand

R right hand

SOURCE References [8] and [15].

Figure B.22 — Horizontal reach range of the upper limbs for grasping for German female subjects in the fifth percentile of body size

Annex C
(informative)

Textual descriptions of figures in Annex B.3

C.1 General

This annex provides textual descriptions of the figures presented in Annex B.3 for persons who, because of their limitations in visual abilities, have difficulties visually retrieving the information of the figures, as expressed in bar graphs or line graphs, including illustrations.

The information presented here is additional to the information described in Clause 5 and Annex B, which should be referred to first. Most of the information here is data tabulated in a simplified form to provide an image of the graphs. Numerical values of the graphs were taken from the original data but rounded down only to provide images of the graphs, or from visual inspections where the original data were not available. Data for error bars such as standard deviations are not presented to avoid too much information. However, averaged values of the standard deviations or ranges between maximum and minimum value are presented in the text.

C.2 Textual descriptions

Figure B.1 — Lifting strength with two hands with comfort, slight effort and extreme effort for male and female subjects of different age groups

The figure shows two line-graphs, for a) male and b) female, that visualize Table C.1, with the X-axis representing age from 0 years to 100 years and the Y-axis a mass to lift in kg from 0 kg to 25 kg. Three curves are drawn: A: with extreme effort, B: with slight effort and C: with comfort. Standard deviations are given for all data points as vertical bars. The average deviations for male and female subjects are ± 3,0 kg and ± 1,9 kg, respectively.

Table C.1 — Numerical values visualized in Figure B.1

X: age years	**Y: A, with extreme effort** kg	**Y: B, with slight effort** kg	**Y: C, with comfort** kg
a) Male			
20 to 29	12,7	8,6	4,8
30 to 39	15,1	9,4	5,4
40 to 49	13,9	8,9	5,3
50 to 59	14,2	9,8	5,3
60 to 69	12,3	8,2	5,4
70 to 79	10	7	4,7
80 to 89	9,2	6,3	4
b) Female			
20 to 29	8,5	6	3,5
30 to 39	10,1	7,1	4,2
40 to 49	9,5	7,2	4,8
50 to 59	9,4	6,5	3,8
60 to 69	8,4	6,2	4,1

Table C.1 *(continued)*

X: age years	Y: A, with extreme effort kg	Y: B, with slight effort kg	Y: C, with comfort kg
70 to 79	7,4	5,4	3,7
80 to 89	6,6	5,5	4,1

Figure B.2 — Carrying strength with one or two hands with comfort or slight effort for young (20-year-old to 39-year-old) and older (60-year-old to 89-year-old) male and female subjects

The figure shows a scatter-plot graph that visualizes Table C.2, with the X-axis representing groups of subjects in each of four measuring conditions: 1: with comfort with one hand, 2: with slight effort with one hand, 3: with comfort with two hands and 4: with slight effort with two hands. The Y-axis shows the mass to carry in kg. Each data point has a maximum and minimum value among the subjects in addition to an average value.

Table C.2 — Numerical values visualized in Figure B.2

X: Carrying style/subject	Y: A, mean kg	Y: B, maximum kg	Y: C, minimum kg
1: comfort carrying with one hand/young, male	1,6	2,0	0,9
1: comfort carrying with one hand/young, female	1,3	1,4	1,2
1: comfort carrying with one hand/older, male	1,6	2,0	1,4
1: comfort carrying with one hand/older, female	1,1	1,4	0,8
2: slight effort carrying with one hand/young, male	3,3	4,2	2,5
2: slight effort carrying with one hand/young, female	1,8	2,6	1,4
2: slight effort carrying with one hand/older, male	2,5	3,7	1,4
2: slight effort carrying with one hand/older, female	2,2	3,6	1,7
3: comfort carrying with two hands/young, male	3,8	4,7	2,7
3: comfort carrying with two hands/young, female	2,8	3,2	2,7
3: comfort carrying with two hands/older, male	4,4	5,7	2,7
3: comfort carrying with two hands/older, female	3,3	3,9	2,4
4: slight effort carrying with two hands/young, male	6,2	6,6	5,9
4: slight effort carrying with two hands/young, female	4,4	5,7	3,7
4: slight effort carrying with two hands/older, male	5,2	6,8	3,7
4: slight effort carrying with two hands/older, female	4,4	5,9	3,2

Figure B.3 — Maximum lifting strength with two hands for different gripping types and heights, (50th percentile data of male and female subjects)

The figure shows a bar graph that visualizes Table C.3, with the X-axis representing gripping style and height and the Y-axis lifting strength in N from 0 N to 2 000 N. Each data point has data of the 50th percentiles for A: male and B: female. The fifth or 95th percentiles are given for each data point as vertical bars to show deviation from the 50th percentile. The average deviations are 380 N for male subjects and 200 N female subjects. Two illustrations are included to show the measuring methods: 1: bottom gripping and 2: side-gripping. Both are shown with the lifting force direction.

Table C.3 — Numerical values visualized in Figure B.3

X: Type of gripping and height	Y: A, lifting strength, male subjects N	Y: B, lifting strength, female subjects N
a: side-gripping, height = 1 350 mm	420	190
b: side-gripping, height = 750 mm	1 270	530
c: side-gripping, height = 400 mm	1 110	490
d: bottom-gripping, height = 1 110 mm	540	250
e: bottom-gripping, height = 500 mm	990	510
f: bottom-gripping, height = 150 mm	970	470

Figure B.4 — Maximum pushing and pulling strength with one hand for male and female subjects of different ages

The figure shows two line-graphs for a) male and b) female that visualize Table C.4, with the X-axis representing age from 0 years to 100 years and the Y-axis pushing or pulling strength in N from 0 N to 800 N. Five curves are drawn for different measuring conditions at different institutions. Standard deviations are given for all data points as vertical bars. The average deviations are ± 99 N and ± 110 N for male and female subjects, respectively. Two illustrations are included to show the measuring methods: 1, DTI; 2, TU, Delft.

Table C.4 — Numerical values visualized in Figure B.4

X: age years	Y: A, pushing a vertical bar, DTI N	Y: B, pushing a horizontal bar, DTI N	Y: C, pulling a vertical bar, DTI N	Y: D, pulling a horizontal bar, DTI N	Y: E, pulling a horizontal bar, TU Delft N
a) Male					
2 to 5	250	250	240	210	—
6 to 10	170	190	150	190	—
11 to 15	173	210	190	180	—
16 to 20	272	280	270	260	—
21 to 30	225	220	240	230	—
31 to 50	457	500	320	350	—
51 to 60	270	370	220	260	—
61 to 70	340	320	290	300	—
71 to 80	330	290	210	210	—
81 to 90	220	190	190	170	—
20 to 30	—	—	—	—	350
31 to 49	—	—	—	—	—
50 to 54	—	—	—	—	340
55 to 59	—	—	—	—	370
60 to 64	—	—	—	—	330
65 to 69	—	—	—	—	320
70 to 74	—	—	—	—	290
75 to 79	—	—	—	—	290
over 80	—	—	—	—	260
b) Female					
2 to 5	250	260	220	230	—

Table C.4 *(continued)*

X: age years	Y: A, pushing a vertical bar, DTI N	Y: B, pushing a horizontal bar, DTI N	Y: C, pulling a vertical bar, DTI N	Y: D, pulling a horizontal bar, DTI N	Y: E, pulling a horizontal bar, TU Delft N
6 to 10	190	180	150	150	—
11 to 15	310	290	260	220	—
16 to 20	350	340	230	240	—
21 to 30	230	220	230	210	—
31 to 50	320	330	230	230	—
51 to 60	320	270	230	230	—
61 to 70	210	190	150	150	—
71 to 80	250	260	240	250	—
81 to 90	260	250	230	220	—
20 to 30	—	—	—	—	240
31 to 49	—	—	—	—	—
50 to 54	—	—	—	—	250
55 to 59	—	—	—	—	260
60 to 64	—	—	—	—	240
65 to 69	—	—	—	—	210
70 to 74	—	—	—	—	190
75 to 79	—	—	—	—	180
over 80	—	—	—	—	160

Figure B.5 — Maximum pushing and pulling strength with two hands for male and female subjects of different ages

The figure is the same as Figure B.4 but for two hands. Table C.5 includes the data for the visualization. The average standard deviations are ± 110 N and ± 120 N for male and female subjects, respectively.

Table C.5 — Numerical values visualized in Figure B.5

X: age years	Y: A, pushing a vertical bar, DTI N	Y: B, pushing a horizontal bar, DTI N	Y: C, pulling a vertical bar, DTI N	Y: D, pulling a horizontal bar, DTI N	Y: E, pushing a horizontal bar, TU Delft N
a) Male					
2 to 5	270	240	230	210	—
6 to 10	200	240	150	180	—
11 to 15	210	200	210	190	—
16 to 20	300	300	280	260	—
21 to 30	300	250	250	240	—
31 to 50	520	540	330	320	—
51 to 60	350	430	230	250	—
61 to 70	410	440	310	330	—
71 to 80	400	360	230	210	—
81 to 90	300	280	190	160	—
20 to 30	—	—	—	—	510

Table C.5 *(continued)*

X: age years	**Y: A, pushing a vertical bar, DTI** N	**Y: B, pushing a horizontal bar, DTI** N	**Y: C, pulling a vertical bar, DTI** N	**Y: D, pulling a horizontal bar, DTI** N	**Y: E, pushing a horizontal bar, TU Delft** N
31 to 49	—	—	—	—	—
50 to 54	—	—	—	—	460
55 to 59	—	—	—	—	490
60 to 64	—	—	—	—	420
65 to 69	—	—	—	—	410
70 to 74	—	—	—	—	360
75 to 79	—	—	—	—	350
over 80	—	—	—	—	300
b) Female					
2 to 5	300	280	260	250	—
6 to 10	220	140	160	150	—
11 to 15	380	320	280	230	—
16 to 20	390	370	230	220	—
21 to 30	260	230	240	210	—
31 to 50	350	330	220	220	—
51 to 60	390	310	260	230	—
61 to 70	230	210	150	160	—
71 to 80	310	310	260	260	—
81 to 90	340	280	210	190	—
20 to 30	—	—	—	—	330
31 to 49	—	—	—	—	—
50 to 54	—	—	—	—	310
55 to 59	—	—	—	—	290
60 to 64	—	—	—	—	290
65 to 69	—	—	—	—	250
70 to 74	—	—	—	—	230
75 to 79	—	—	—	—	220
over 80	—	—	—	—	170

Figure B.6 — Maximum pressing and lifting strength with feet for male and female subjects of different ages

The figure shows two line-graphs for a) male and b) female that visualize Table C.6, with the X-axis representing age from 0 years to 100 years and the Y-axis pressing or lifting strength with feet in N from 0 N to 900 N. Four curves are drawn for different measuring conditions: A: pressing a bar, B: lifting a bar, C: pressing a pedal, D: lifting a pedal. Standard deviations are given for all data points as vertical bars. The average deviations are ± 73 N and ± 60 N for male and female subjects, respectively. Two illustrations are included to show the measuring methods: 1, pressing a bar, 2, lifting a bar, both by foot.

Table C.6 — Numerical values visualized in Figure B.6

X: age years	Y: A, pressing a bar N	Y: B, lifting a bar N	Y: C pressing a pedal N	Y: D, lifting a pedal N
a) Male				
2 to 5	90	80	50	40
6 to 10	170	150	90	70
11 to 15	470	280	220	140
16 to 20	660	410	330	170
21 to 30	630	340	320	160
31 to 50	670	330	310	200
51 to 60	590	220	280	180
61 to 70	560	270	250	160
71 to 80	420	210	180	130
81 to 90	300	210	160	130
b) Female				
2 to 5	90	80	50	30
6 to 10	230	160	130	100
11 to 15	430	200	180	120
16 to 20	400	220	180	100
21 to 30	470	230	230	140
31 to 50	520	240	210	130
51 to 60	350	240	150	110
61 to 70	340	180	160	120
71 to 80	360	220	140	130
81 to 90	260	150	120	110

Figure B.7 — Grip diameter measured using a cone for male and female subjects of different ages

The figure shows a bar-graph that visualizes Table C.7, with the X-axis representing age from 20 years to over 80 years and the Y-axis grip diameter in cm from 2,0 cm to 5,5 cm. Each data point has data for A, male and B, female subjects. Standard deviations are given for all data points as vertical bars. The average deviations are ± 0,33 cm and ± 0,34 cm for male and for female subjects respectively. An illustration is included to show the measuring method.

Table C.7 — Numerical values visualized in Figure B.7

X: age years	Y: A, male subjects N	Y: B, female subjects N
20 to 30	4,3	3,9
31 to 49	—	—
50 to 54	4,2	3,9
55 to 59	4,1	4,0
60 to 64	4,2	3,9
65 to 69	4,1	3,8
70 to 74	4,1	3,9
75 to 79	4,1	3,7
over 80	3,9	3,6

Figure B.8 — Steadiness of hand–eye coordination for male and female subjects of different ages

The figure shows a bar graph that visualizes Table C.8, with the X-axis representing age from 20 years to over 80 years and the Y-axis the diameter of a hole from 2,0 mm to 7,5 mm. Each data point has data for A, male subjects and B, female subjects. Standard deviations are given for all data points as vertical bars. The average deviation is ± 1,0 mm for both male and female subjects. An illustration is included to show the measuring method for hand steadiness.

Table C.8 — Numerical values visualized in Figure B.8

X: age years	**Y: A,** **male subjects** mm	**Y: B,** **female subjects** mm
20 to 30	4,4	4,2
31 to 49	—	—
50 to 54	4,5	4,9
55 to 59	4,8	4,8
60 to 64	5,0	5,0
65 to 69	5,2	5,0
70 to 74	5,4	4,8
75 to 79	5,7	5,2
over 80	6,2	5,5

Figure B.9 — Maximum angle of the wrist for inward (pronation) and outward (supination) rotation for male and female subjects of different ages

The figure shows two bar graphs for a) inward rotation (pronation) and b) outward rotation (supination) that visualize Table C.9, with the X-axis representing age from 20 years to over 80 years and the Y-axis maximum rotation angle of the wrist in degrees from 20 ° to 110 °. Each data point has a pair of data for A, male subjects and B, female subjects. The data are the fifth percentiles: no standard deviations are shown. Two illustrations are included to show the measuring methods: 1: inward rotation and 2: outward rotation.

Table C.9 — Numerical values visualized in Figure B.9

X: age years	**Y: A,** **male subjects** degrees	**Y: B,** **female subjects** degrees
a) Inward rotation (pronation)		
20 to 30	75	77
31 to 49	—	—
50 to 54	76	66
55 to 59	79	89
60 to 64	84	82
65 to 69	79	84
70 to 74	80	82
75 to 79	77	89
over 80	78	98
b) Outward rotation (supination)		
20 to 30	64	69
31 to 49	—	—
50 to 54	46	59
55 to 59	56	62

Table C.9 *(continued)*

X: age years	**Y: A, male subjects** degrees	**Y: B, female subjects** degrees
60 to 64	62	57
65 to 69	50	60
70 to 74	51	55
75 to 79	55	49
over 80	37	49

Figure B.10 — Subjective evaluation of diameter of a circular dial for ease of rotation with fingers for young (in their 20s and 30s) and older (in their 60s to 80s) subjects

The figure shows a bar graph that visualizes Table C.10 with the X-axis representing dial diameter for 15 mm, 20 mm, 25 mm and 35 mm and the Y-axis subjective evaluation score for ease of operation of a five-point scale from 1, difficult to 5, easy. Each data point has data for A, young people and B, older people. No standard deviations are presented. An illustration is included to show the measuring method for operating a circular dial on a vertical panel with a separate figure to indicate the dial diameter, *d*.

Table C.10 — Numerical values visualized in Figure B.10

X: dial diameter mm	**Y: A, young subjects**	**Y: B, older subjects**
15	3,9	3,7
20	4,3	4,1
25	4,3	4,0
35	3,3	3,2

Figure B.11 — Preferred stroke length for pushing a button with the forefinger for young (20-year-old to 40-year-old) and older (over 65-year-old) subjects

The figure shows two line graphs for a) young people and b) older people that visualize Table C.11, with the X-axis representing stroke length from 0 mm to 4,0 mm and the Y-axis the preference score of operation from 0, least preferred to 7, most preferred. Three curves are depicted in each graph for different pushing directions: A, downward; B, oblique angle; and C, forward. No standard deviation is presented. An illustration is included to show operation of pushing a button for a case at an oblique angle.

Table C.11 — Numerical values visualized in Figure B.11

X: stroke length mm	**Y: A, downward pushing**	**Y: B, oblique angle**	**Y: C, forward pushing**
a) Young subjects			
0,0	1,5	4,0	5,9
0,5	5,5	5,0	5,9
1,0	5,0	5,6	5,0
1,5	4,0	3,1	3,4
2,0	3,0	3,7	3,5
2,5	0,9	2,0	1,8
3,0	1,6	0,1	0,0
3,5	0,0	0,6	0,5
b) Older subjects			

Table C.11 *(continued)*

X: stroke length mm	Y: A, downward pushing	Y: B, oblique angle	Y: C, forward pushing
0,0	1,0	3,5	3,4
0,5	5,0	5,0	3,9
1,0	5,5	4,5	4,3
1,5	3,6	4,0	2,5
2,0	3,6	2,5	3,0
2,5	1,6	1,5	1,5
3,0	1,1	1,1	0,4
3,5	0,1	0,0	2,5

Figure B.12 — Maximum grip strength of one hand for male and female subjects of different ages

The figure shows two line-graphs for a) male and b) female that visualize Table C.12, with the X-axis representing age from 0 years to 100 years and the Y-axis grip strength from 0 N to 700 N. Four curves are depicted in each graph for the representative data sources: A, Mathiowetz et al.; B, Angst et al.; C, TU Delft; D, MEXT. In addition, seven curves of the Leong et al. data are shown: E, Europe and North America; F, three curves of South America, the Middle East and China; G, three curves of Africa, Southeast Asia and South Asia. Standard deviations are given for all data points, except for the Leong et al. data, as vertical bars. The average deviations are ± 120 N and ± 49 N for male and female subjects, respectively. Two illustrations are included to show the measuring methods: 1, for Mathiowetz et al.; Angst et al.; TU Delft; and Leong et al. and 2, for MEXT.

Table C.12 — Numerical values visualized in Figure B.12

X: age years	Y: A, Mathiowetz et al. N	Y: B, Angst et al. N	Y: C, TU Delft N	Y: D, MEXT N	Y: E, Leong et al., Europe and North America N	Y: F, Leong et al., South America N	Y: F, Leong et al., Middle East N	Y: F: Leong et al., China N	Y: G, Leong et al., Africa N	Y: G, Leong et al., Southeast Asia N	Y: G, Leong et al., South Asia N
a) Male											
6	—	—	—	90	—	—	—	—	—	—	—
7	—	—	—	110	—	—	—	—	—	—	—
8	—	—	—	130	—	—	—	—	—	—	—
9	—	—	—	150	—	—	—	—	—	—	—
10	—	—	—	170	—	—	—	—	—	—	—
11	—	—	—	200	—	—	—	—	—	—	—
12	—	—	—	240	—	—	—	—	—	—	—
13	—	—	—	290	—	—	—	—	—	—	—
14	—	—	—	340	—	—	—	—	—	—	—
15	—	—	—	370	—	—	—	—	—	—	—
16	—	—	—	400	—	—	—	—	—	—	—
17	—	—	—	420	—	—	—	—	—	—	—

[a] For age 18 years to 19 years.

[b] For age 20 years to 29 years.

[c] For age over 75 years.

[d] For age over 80 years.

Table C.12 *(continued)*

X: age years	Y: A, Mathiowetz et al. N	Y: B, Angst et al. N	Y: C, TU Delft N	Y: D, MEXT N	Y:, E, Leong et al., Europe and North America N	Y: F, Leong et al., South America N	Y: F, Leong et al., Middle East N	Y: F: Leong et al., China N	Y: G, Leong et al., Africa N	Y: G, Leong et al., Southeast Asia N	Y: G, Leong et al., South Asia N
18	—	—	—	420	—	—	—	—	—	—	—
19	—	500[a]	—	420	—	—	—	—	—	—	—
20 to 24	540	530	540[b]	450	—	—	—	—	—	—	—
25 to 29	540	520	—	460	—	—	—	—	—	—	—
30 to 34	540	540	—	460	—	—	—	—	—	—	—
35 to 39	530	550	—	460	—	—	—	—	—	—	—
40 to 44	520	530	—	460	—	—	—	—	—	—	—
45 to 49	490	510	—	460	—	—	—	—	—	—	—
50 to 54	510	500	510	450	—	—	—	—	—	—	—
55 to 59	450	530	480	440	—	—	—	—	—	—	—
60 to 64	400	470	450	420	—	—	—	—	—	—	—
65 to 69	410	420	420	390	—	—	—	—	—	—	—
70 to 74	340	410	390	370	—	—	—	—	—	—	—
75 to 79	290[c]	360	370	340	—	—	—	—	—	—	—
80 to 84	—	300	330[d]	—	—	—	—	—	—	—	—
over 85	—	220	—	—	—	—	—	—	—	—	—
35 to 40	—	—	—	—	490	440	440	440	360	390	340
41 to 50	—	—	—	—	480	420	420	420	370	360	320
51 to 60	—	—	—	—	450	400	390	390	310	320	300
61 to 70	—	—	—	—	410	360	340	350	290	280	260
b) Female											
6	—	—	—	90	—	—	—	—	—	—	—

[a] For age 18 years to 19 years.

[b] For age 20 years to 29 years.

[c] For age over 75 years.

[d] For age over 80 years.

Table C.12 *(continued)*

X: age years	Y: A, Mathio-wetz et al. N	Y: B, Angst et al. N	Y: C, TU Delft N	Y: D, MEXT N	Y:, E, Leong et al., Europe and North America N	Y: F, Leong et al., South America N	Y: F, Leong et al., Middle East N	Y: F: Leong et al., China N	Y: G, Leong et al., Africa N	Y: G, Leong et al., South-east Asia N	Y: G, Leong et al., South Asia N
7	—	—	—	100	—	—	—	—	—	—	—
8	—	—	—	120	—	—	—	—	—	—	—
9	—	—	—	140	—	—	—	—	—	—	—
10	—	—	—	160	—	—	—	—	—	—	—
11	—	—	—	190	—	—	—	—	—	—	—
12	—	—	—	210	—	—	—	—	—	—	—
13	—	—	—	240	—	—	—	—	—	—	—
14	—	—	—	250	—	—	—	—	—	—	—
15	—	—	—	250	—	—	—	—	—	—	—
16	—	—	—	260	—	—	—	—	—	—	—
17	—	—	—	270	—	—	—	—	—	—	—
18	—	—	—	260	—	—	—	—	—	—	—
19	—	310[a]	—	270	—	—	—	—	—	—	—
20 to 24	310	330	340[b]	270	—	—	—	—	—	—	—
25 to 29	330	340	—	280	—	—	—	—	—	—	—
30 to 34	350	330	—	280	—	—	—	—	—	—	—
35 to 39	330	350	—	290	—	—	—	—	—	—	—
40 to 44	310	350	—	290	—	—	—	—	—	—	—
45 to 49	280	330	—	290	—	—	—	—	—	—	—
50 to 54	290	330	300	280	—	—	—	—	—	—	—
55 to 59	260	310	290	270	—	—	—	—	—	—	—
60 to 64	250	280	280	260	—	—	—	—	—	—	—
65 to 69	220	290	260	250	—	—	—	—	—	—	—
70 to 74	220	260	250	230	—	—	—	—	—	—	—
75 to 79	190 [c]	250	230	220	—	—	—	—	—	—	—

[a] For age 18 years to 19 years.

[b] For age 20 years to 29 years.

[c] For age over 75 years.

[d] For age over 80 years.

Table C.12 *(continued)*

X: age years	Y: A, Mathiowetz et al. N	Y: B, Angst et al. N	Y: C, TU Delft N	Y: D, MEXT N	Y:, E, Leong et al., Europe and North America N	Y: F, Leong et al., South America N	Y: F, Leong et al., Middle East N	Y: F: Leong et al., China N	Y: G, Leong et al., Africa N	Y: G, Leong et al., South-east Asia N	Y: G, Leong et al., South Asia N
80 to 84	—	190	200 [d]	—	—	—	—	—	—	—	—
over 85	—	170	—	—	—	—	—	—	—	—	—
35 to 40	—	—	—	—	290	280	260	270	210	230	230
41 to 50	—	—	—	—	290	260	250	270	240	220	210
51 to 60	—	—	—	—	260	250	230	260	200	200	190
61 to 70	—	—	—	—	250	230	210	230	180	180	190

[a] For age 18 years to 19 years.

[b] For age 20 years to 29 years.

[c] For age over 75 years.

[d] For age over 80 years.

Figure B.13 — Maximum twisting strength of the wrist for male and female subjects of different ages

The figure shows two line graphs for a) male and b) female, that visualize Table C.13, with the X-axis representing age from 0 years to 100 years and the Y-axis twisting torque from 0 Nm to 8 Nm. Seven curves are depicted in each graph for different data sources (NITE and DTI) and different measuring conditions (inward or outward rotation, smooth or ridged knob, horizontal or vertical orientation). Standard deviations are given for all data points as vertical bars. The average deviations are ± 1,2 Nm and ± 1,0 Nm for male and female subjects, respectively. Four illustrations are given to show the measuring methods: 1, a circular knob at vertical orientation by NITE; 2, a circular knob at horizontal orientation by NITE; 3, a circular knob at horizontal orientation by DTI; and 4, a ridged knob at horizontal orientation by DTI.

Table C.13 — Numerical values visualized in Figure B.13

X: age years	Y: A, circular-knob, 50 mm diameter, outward-rotation, vertical-orientation, NITE Nm	Y: B, circular-knob, 50 mm diameter, outward-rotation, horizontal-orientation, NITE Nm	Y: C, circular-knob, 50 mm diameter, inward-rotation, vertical-orientation, NITE Nm	Y: D, circular-knob, 50 mm diameter, inward-rotation, horizontal-orientation, NITE Nm	Y: E, circular-knob, 40 mm diameter, clockwise-rotation, vertical-orientation, DTI Nm	Y: F, ridged-knob, 40 mm diameter, clockwise-rotation, vertical-orientation, DTI Nm	Y: G, ridged-knob, 40 mm diameter, clockwise-rotation, horizontal-orientation, DTI Nm
a) Male							
20 to 29	3,7	4,7	2,9	4,8	—	—	—
30 to 39	3,2	4,7	3,7	4,8	—	—	—