

16.400/16.453

Human Factors Engineering

Anthropometry/Ergonomics



Massachusetts Institute of Technology

Definition

Anthropometry = **Anthro** + **metry**
(human) (measurement)

Anthropometry

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- **Anthropometry** is the scientific measurement and collection of data about human physical characteristics and the application (engineering anthropometry) of these data in the design and evaluation of systems, equipment, manufactured products, human environments, and facilities.
- Cockpits, air traffic control work stations, maintenance, passengers, other crew stations

Anthropometry/Ergonomics

Measuring the Human Size

Determining Workplace Locations

Verifying Required Forces and Physical Loads

Workspace Design

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- Monitoring
 - ATC
 - Process control
 - Medical applications
- Control
 - Cockpit
 - Remotely piloted vehicles
 - UAVs, UGVs, UUVs
 - Remote surgery
 - Supervisory control
- Must consider human-environment interactions as well as physical and cognitive limitations

How to Accomplish the Interface

- Make the Man Fit the Job
 - Selection
 - Training
 - Motivation

- Make Job Fit the Man (or Woman)
 - Adjustability
 - Load Regulation

Some Common Errors

- Using the Wrong Subject Population
 - Age
 - Gender
 - Race
 - Fitness

Design Considerations

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- Design reference points and zones
 - o Seat reference points
 - o Arm rotation points
 - o Eye reference points or zones
 - o Visual envelopes
 - o Mobility and/or comfort adjustment ranges
- Dynamic measures
 - o Range & strength
 - o Grip
 - o Grasp
 - o Exerted forces
 - Push, pull, vertical
 - Lifting & carrying

C/D Layout

- Central Limit Theorem assures Normality, BUT
- Beware of the 3 Sigma outliers

- Measurements co-vary (e.g. height, and reach) BUT
- Significant variations exist among the various measures

Principles for C/D Layout

- Location
 - Operational importance of C/Ds
 - Frequency of use of C/Ds
- Grouping
 - Functional
 - Sequential
 - Topological
- C/D Identification
- Stereotypical Layouts
- Individual C/D Constraints
 - Manipulability of control
 - Visibility of display

Ergonomics Design Flow

- Priorities
 - Primary visual tasks & their controls
 - Emergency controls
 - Control/display relations
 - Functional/sequential grouping
 - Frequency-of-use and consistency in layout
- Priorities in automobile WS

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Standing Operator Workplace

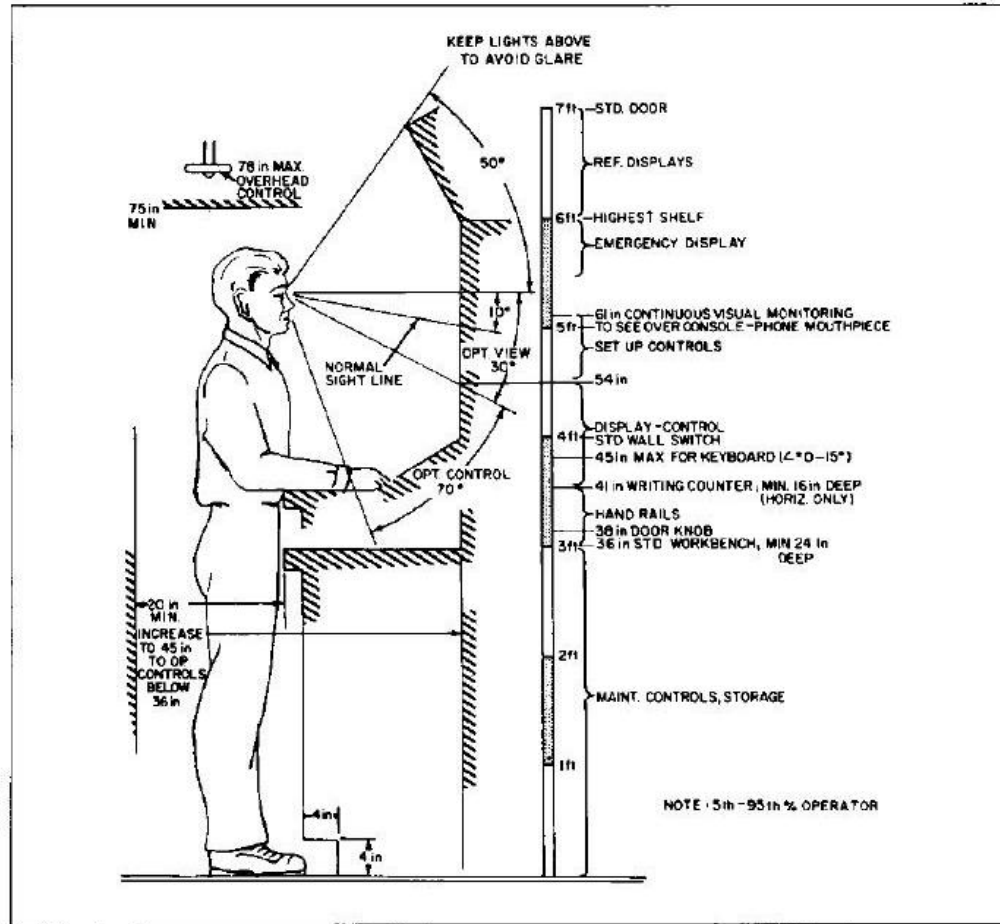


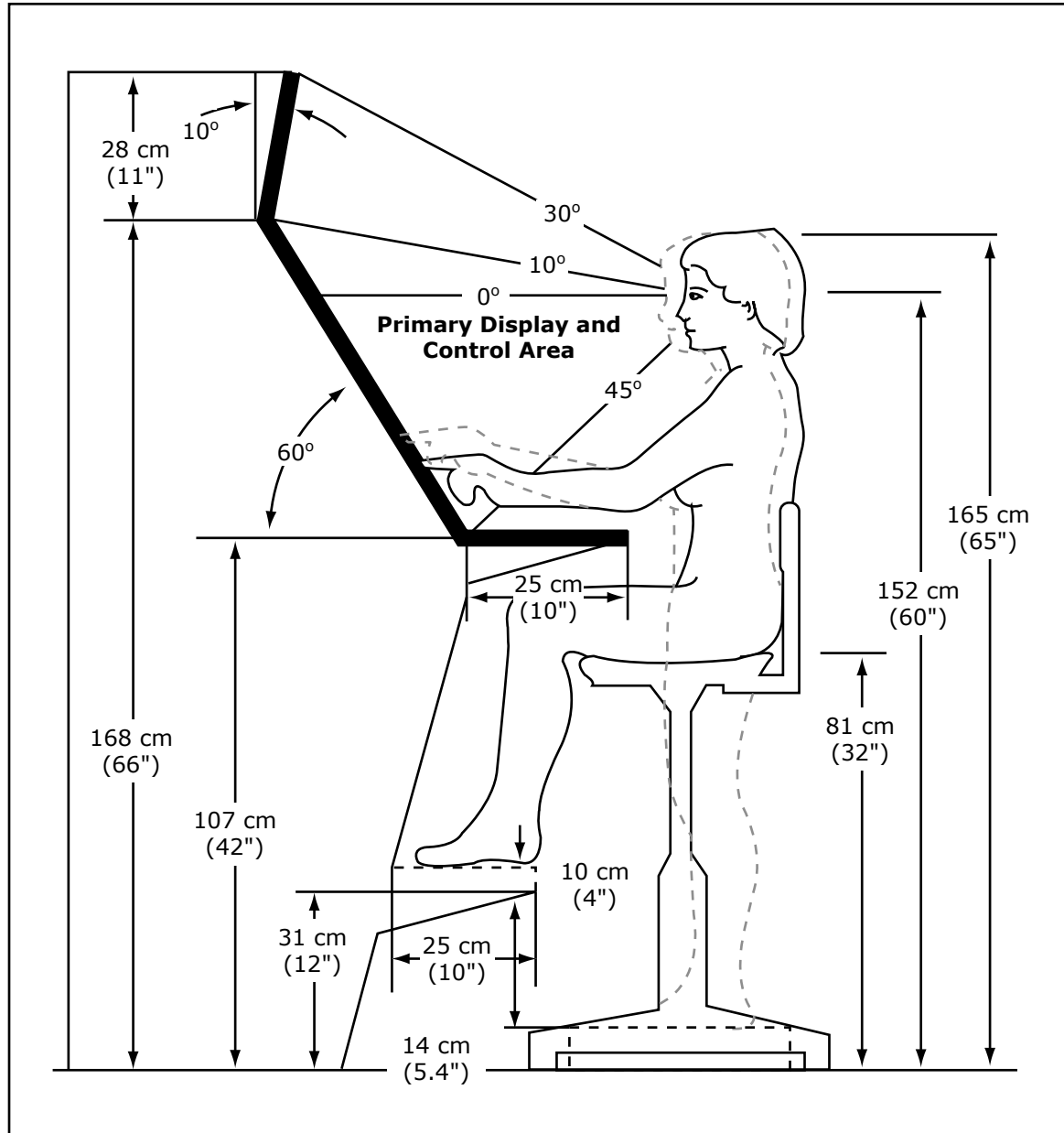
FIGURE 11-2.
Suggested Parameters for Mockup of Standing Operator Workplaces

This image is in the public domain. Source: Department of Defense.

Vehicle Operator Workplace

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Control/Display Locations



Reach

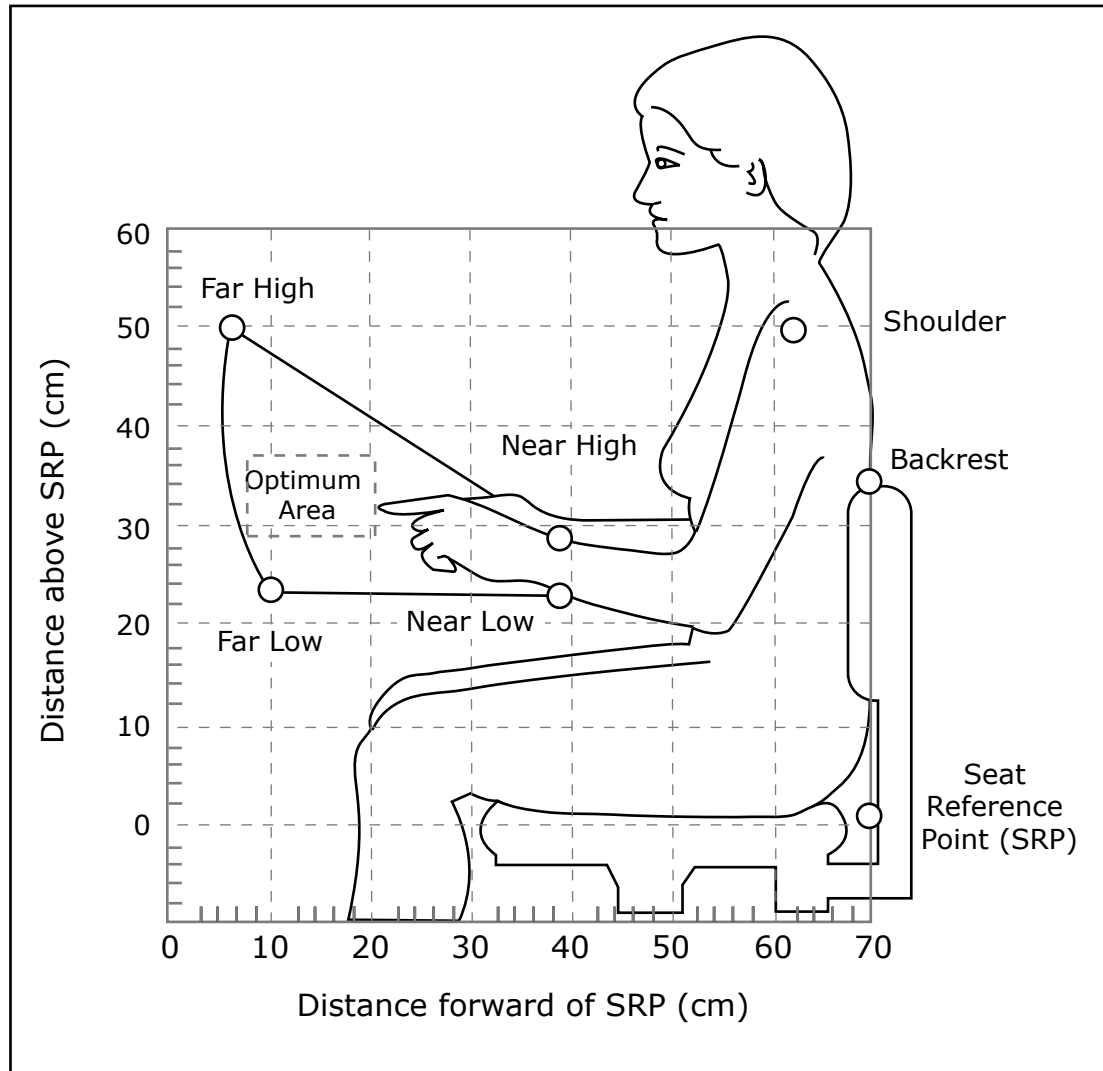


Image by MIT OpenCourseWare.

Standing Control/Display Areas

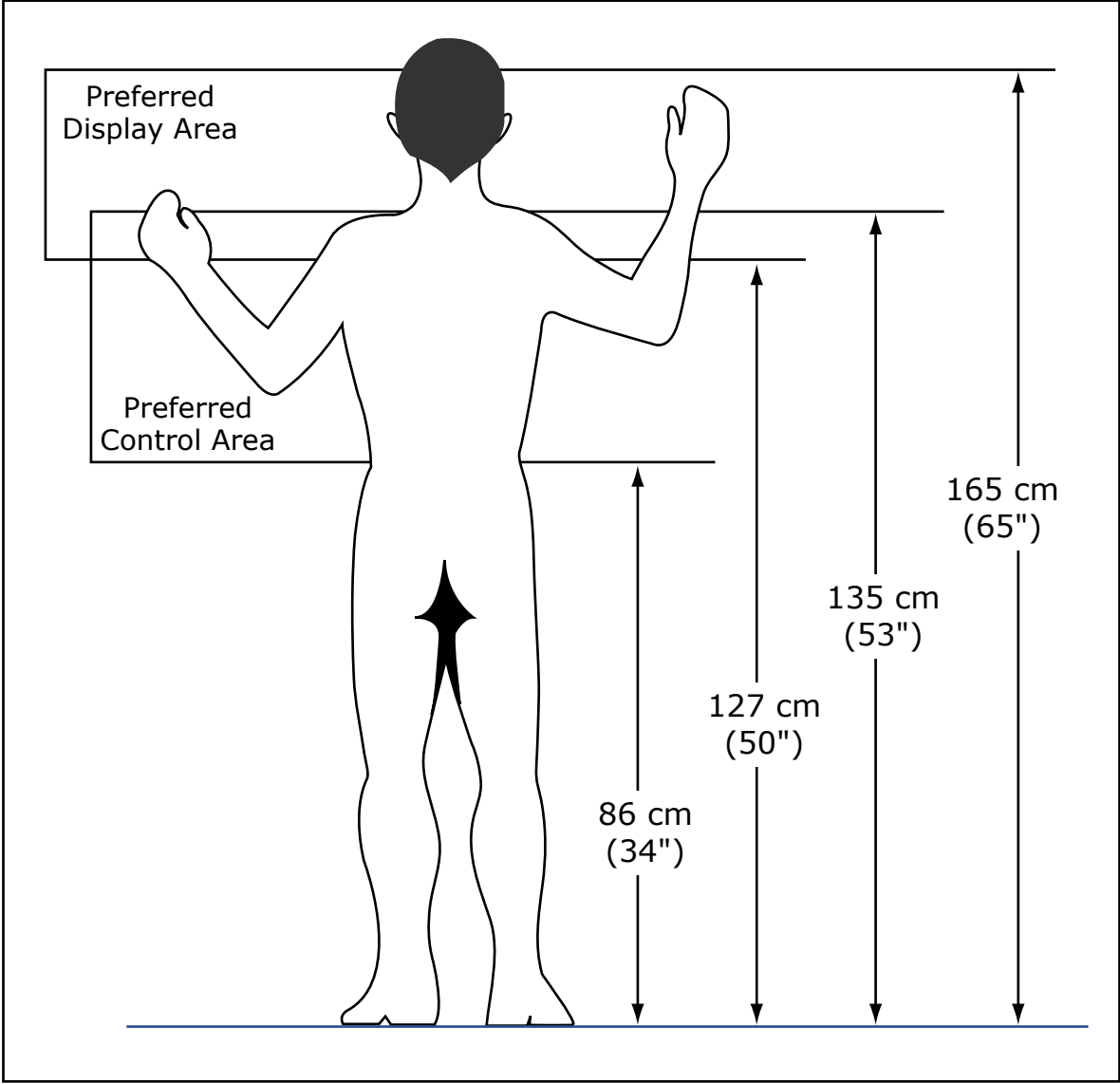


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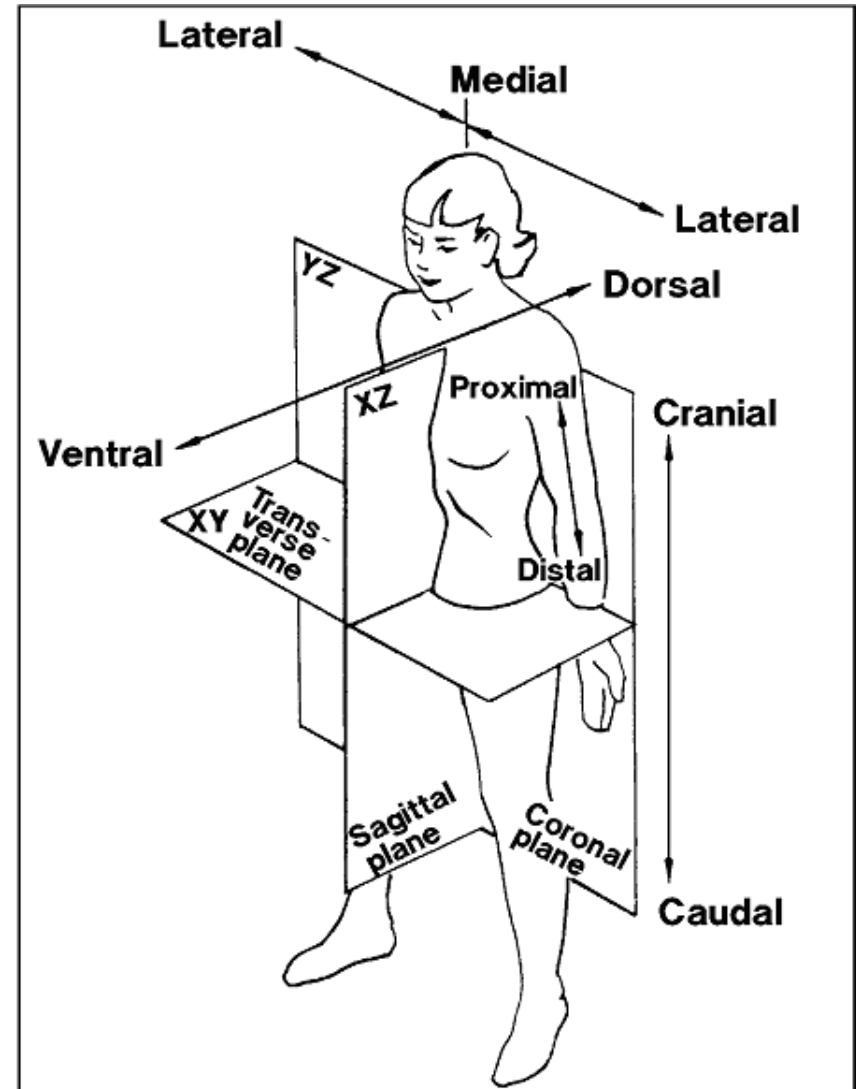
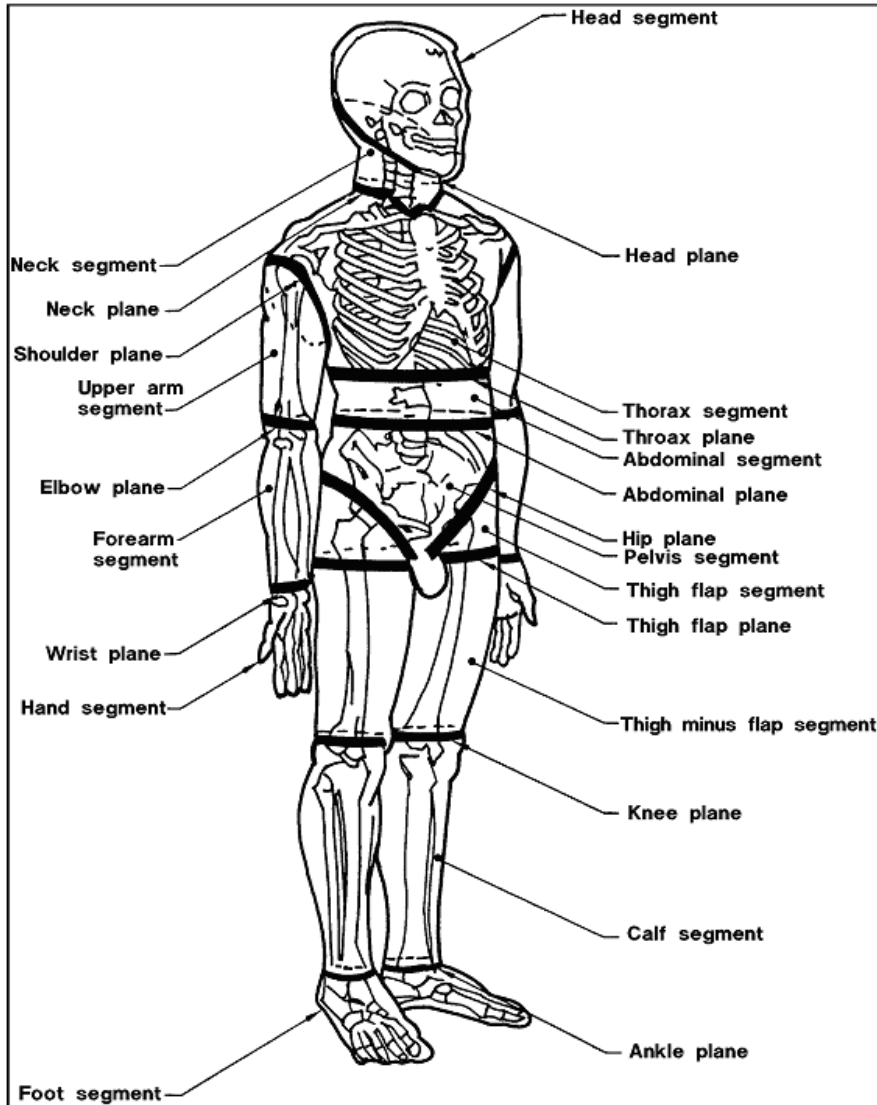
Representative Human Models

- A small group of humanoids representing a designated percentage (e.g., 90%) of the target population for product design based on anthropometric data
- Benefits of RHMs in anthropometric design
 - Efficient ergonomic design and evaluation
 - Good fit between products and the target users.

Applied Anthropometry

Figures 13.1 and 13.4 removed due to copyright restrictions. Source: Sanders, Mark S., and Ernest J. McCormick. *Human Factors in Engineering and Design*. 7th ed. McGraw-Hill, 1993. ISBN: 9780070549012.

Reference Planes



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Body Size Measurements

Type	Description
Height	A straight-line, point-to-point vertical measurement from a reference plane (floor or seat-pan).
Breadth	A straight-line, point-to-point horizontal measurement running across the body or segment.
Depth (Thickness)	A straight-line, point-to-point measurement running fore-aft.
Length	A straight-line, point-to-point measurement between landmarks on the body.
Circumference	A closed measurement that follows a body contour.
Curvature	A point-to-point, but not closed, measurement that follows a body contour.

Workplace Design

- General approach
 - Plan the whole, then the detail
 - Plan the ideal, then the practical
 - Systems requirements → process/equipment
 - Process/equipment → workplace layout
 - Evaluate alternatives: models, mockups
- Workplace layout
 - Define what the operator needs to see outside ws, inside ws, other people/equipment
 - Define what operator needs to hear to communicate to with others, signals, alarms, equipment
 - Specify what operator needs to control hand/foot controls, latches, seat adj, emergency
 - Determine body clearances

Reach Measurements

Images removed due to copyright restrictions.

Preferred Postures

Images removed due to copyright restrictions.

Measurement Techniques

Technique	Description
Mechanical device	The body sizes are obtained by measuring the body parts directly.
Photogrammetry	The body sizes are obtained by measuring the body parts on the photographic image.
Laser scanner	The body sizes are extracted from the digital body.

Factors Effecting Body Size

- The distributions of body sizes are known to be normal or similar to normal
- Sources of variability
 - Age
 - Gender
 - Racial and ethnic group
 - Occupation
 - Diurnal
 - Secular trend

Height Growth in Japan

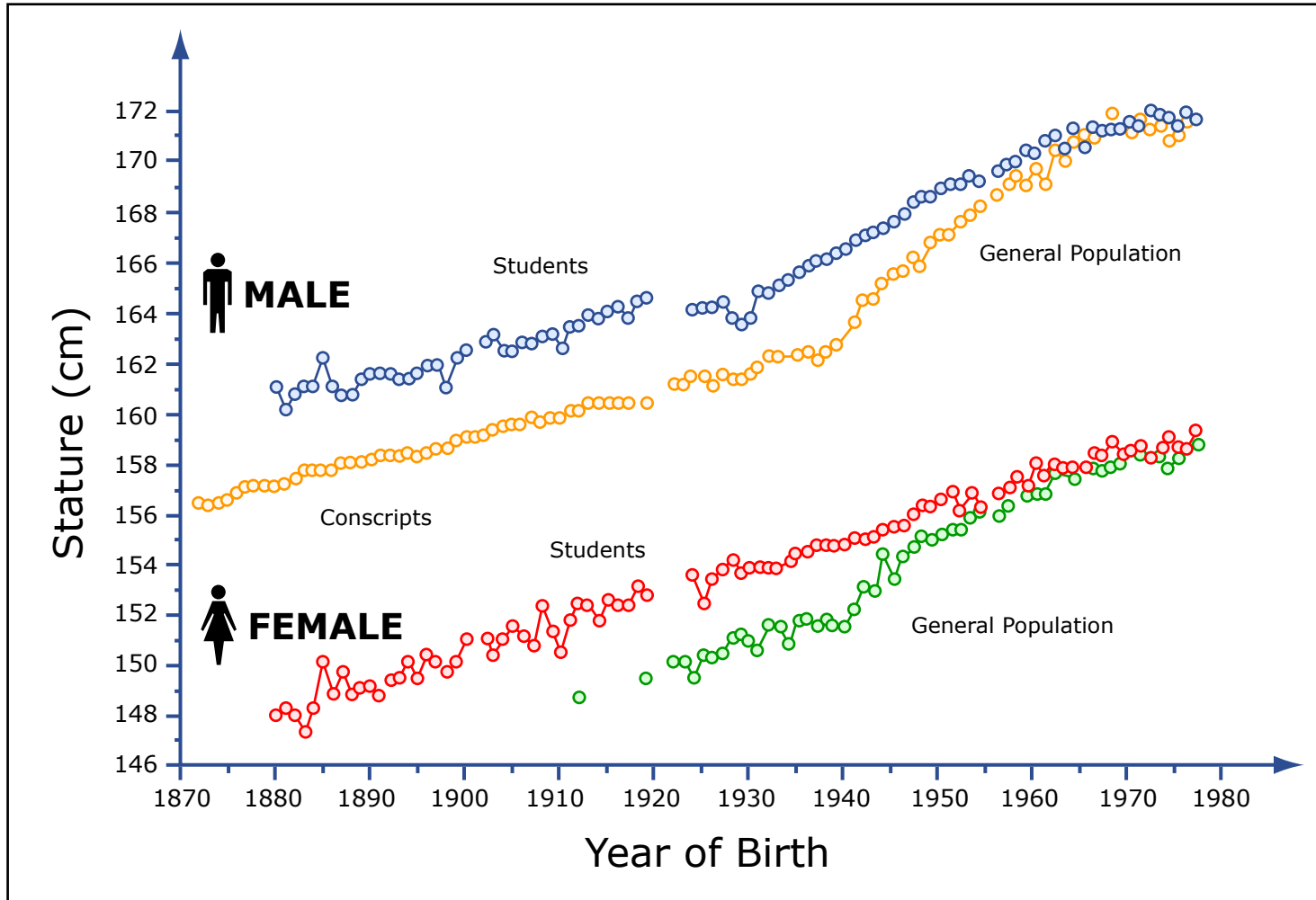
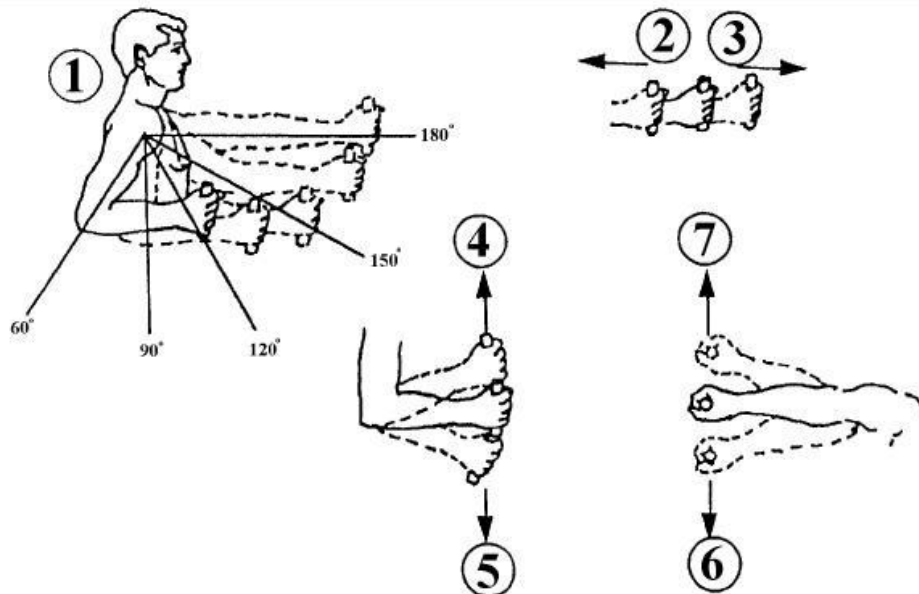


Image by MIT OpenCourseWare.

Exhibit 14.5.2.1 Male muscle strength of the arm, hand, and thumb for control forces (5th percentile values)



Arm strength N (lb) Design criteria levels

Degree elbow flexion	2		3		4		5		6		7	
	L	R	L	R	L	R	L	R	L	R	L	R
180°	177.6 (40)	184.8 (41.6)	149.6 (33.6)	177.6 (40)	32 (7.2)	49.6 (11.2)	46.6 (10.4)	60.8 (13.6)	46.6 (10.4)	71.2 (16)	28.8 (6.4)	49.6 (11.2)
150°	149.6 (33.6)	199.2 (44.8)	106.4 (24)	149.6 (33.6)	53.6 (12)	64 (14.4)	64 (14.4)	71.2 (16)	53.6 (12)	71.2 (16)	28.8 (6.4)	53.6 (12)
120°	120.8 (27.2)	149.6 (33.6)	92.8 (20.8)	128 (28.8)	60.8 (13.6)	85.6 (19.2)	74.4 (16.8)	92.8 (20.8)	71.2 (16)	78.4 (17.6)	36 (8)	53.6 (12)
90°	113.6 (25.6)	132 (29.6)	78.4 (17.6)	128 (28.8)	60.8 (13.6)	71.2 (16)	74.4 (16.8)	92.8 (20.8)	56.8 (12.8)	64 (14.4)	36 (8)	56.8 (12.8)
60°	92.8	85.6	78.4	120.8	53.6	71.2	64	71.2	60.8	71.2	42.4	60.8

This image is in the public domain.
Source: US Dept. of Transportation.



- D. Standing two-handed push: 150 cm (59.1 in) level.** Standing erect with feet 45 cm (17.7 in) apart grasping from below, both sides of a 45 cm (17.7 in) handle located directly in front, 150 cm (59.1 in) above standing surface, pushing upward using arms and shoulders

Strength measurements	5th Percentile		95th Percentile	
	Male	Female	Male	Female
Mean force (N)	408.8	153.5	1016.9	379.9
Mean force (lbf)	(91.9)	(34.51)	(228.61)	(85.41)
Peak force (N)	472.8	187.7	1094.3	430.1
Peak force (lbf)	(106.29)	(42.20)	(246.02)	(96.69)



- E. Standing one-handed pull: 100 cm (39.4 in) level.** Standing erect with feet 15 cm (5.9 in) apart dominant hand grasping underside of D-ring located directly to the side, 100 cm (39.4 in) above standing surface, pulling upward while keeping shoulder square and other arm relaxed at side

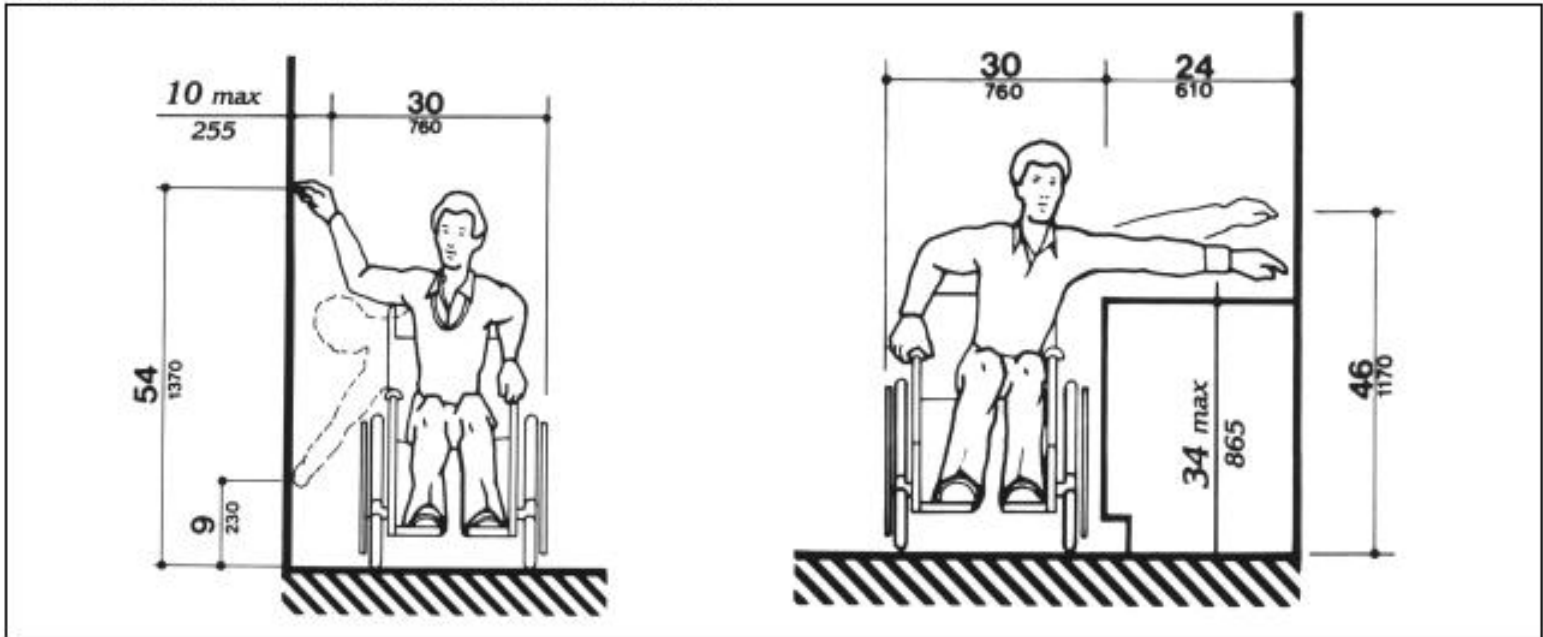
Strength measurements	5th Percentile		95th Percentile	
	Male	Female	Male	Female
Mean force (N)	214.8	102.8	627.6	283.8
Mean force (lbf)	(48.29)	(23.11)	(141.09)	(63.8)
Peak force (N)	258.9	131.7	724.2	322.5
Peak force (lbf)	(58.20)	(29.61)	(162.81)	(72.50)



- F. Seated one-handed pull: seat centerline 45 cm (39.4 in) level.** Sitting erect with feet 55 cm (21.7 in) apart, dominant hand grasping underside of D-ring located directly to the front, 45 cm (17.7 in) above the floor, pulling upward while keeping shoulder square and other arm resting in lap

Strength measurements	5th Percentile		95th Percentile	
	Male	Female	Male	Female
Mean force (N)	222.3	106.3	678.4	391.9
Mean force (lbf)	(49.98)	(23.90)	(152.51)	(88.11)
Peak force (N)	273.1	127.2	758.4	450.6
Peak force (lbf)	(61.40)	(28.60)	(170.50)	(101.30)

Exhibit 14.6.4 Side reach from a wheelchair.



This image is in the public domain. Source: US Dept. of Transportation.

Design for Repetitive Tasks

- Work related Musculoskeletal Disorders
 - Housemaids Knee
 - Instrumentalists – “Finger Overuse”
 - Carpal tunnel syndrome (most of us)
 - Force over 1kg
 - Time < 10 sec
 - Repetitive operations
 - Lack of regular breaks

Lifting Disorders

- Safe techniques for Lifting
- Safe loads
- Maximum number of lifts
- *The EU guideline states “manual handling should be avoided as much as possible”*
- Lower Back Injuries
- Effectiveness of Training
- Abdominal Belts

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