King Saud University

College of Engineering

IE – 341: “Human Factors”

Fall – 2014 (1st Sem. 1435-6H)

Applied Anthropometry, Work-Space Design
Part I – Anthropometry
(Chapter 13)

Prepared by: Ahmed M. El-Sherbeeny, PhD
*(Adapted from Slides by: *Dr. Khaled Al-Saleh*)

Lesson Overview

- Introduction
- Anthropometry
  - Static Dimensions
  - Dynamic (Functional) Dimensions
  - Discussion: Static, Dynamic Dimensions
- Use of Anthropometric Data
  - Principles in the Application of Anthropometric Data
    - Designing for Extreme Individuals
    - Designing for Adjustable Range
    - Designing for the Average
    - Discussion of Anthropometric Design Principles

Introduction

- Poor design features of tools, facilities, e.g.:
  - uncomfortable chairs
  - high shelves
  - too low or too high sinks
  - clothes too tight/loose in certain parts
  - equipment with no space to insert repair tool
- Failure to design equipment, facilities to fit people's physical dimensions ⇒
  - not suitable to human use
  - physiological disorders, diseases:
    - e.g. poorly designed seats ⇒ back injury, muscle aches, pain: neck + shoulder, leg circulatory problems
- Chapter: designing tools to fit physical dimensions of people, with emphasis on:
  - seats, seated workstations

Anthropometry

- Def^n: "measurement of humans for purposes of understanding human physical variation"
- Involves measurement of:
  - body dimensions
  - other body physical characteristics, e.g.:
    - volumes
    - center of gravity
    - masses of body segments
- Body dimensions
  - applies to wider range of design problems (here)
  - types of body measurement:
    - static
    - dynamic (functional)
- *Engineering* Anthropometry:
  - applying these 2 types of data to designing objects

Cont. Anthropometry

Static Dimensions

- Def^{n}: measurements taken when body is in fixed (static) position
- Consist of:
  - skeletal dimensions (bet. centers of joints e.g. bet. elbow & wrist)
  - contour dimensions (skin-surf. dimensions e.g head circum.)
- Many dimensions can be measured:
  - *NASA Anthropometric Source Book*: 973 measurements from 91 worldwide surveys
- Dimensions applications (many):
  - specific applications (helmets, earphones, gloves)
  - general utility of measuring certain body features:
    - figure 13-1 + table 13-1 (next 2 slides)

“head-measurer”: tool used for research early 1910s (Wikipedia)

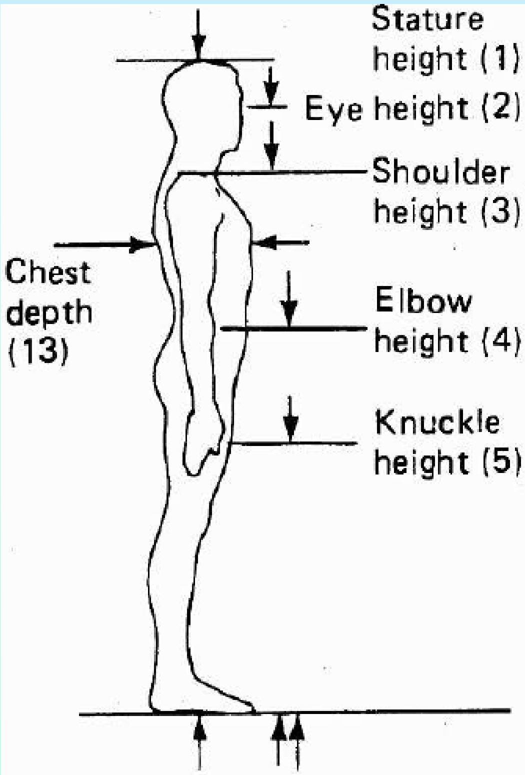
Cont. Anthropometry

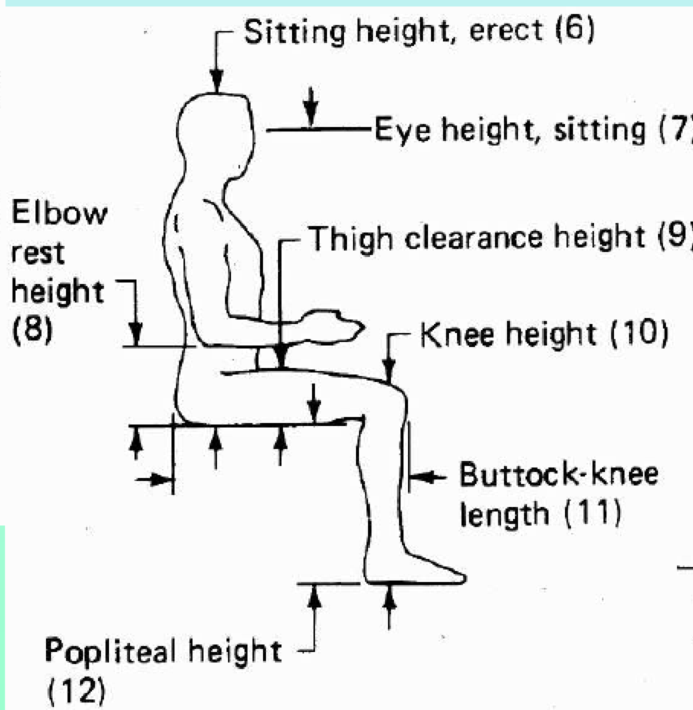
Cont. Static Dimensions

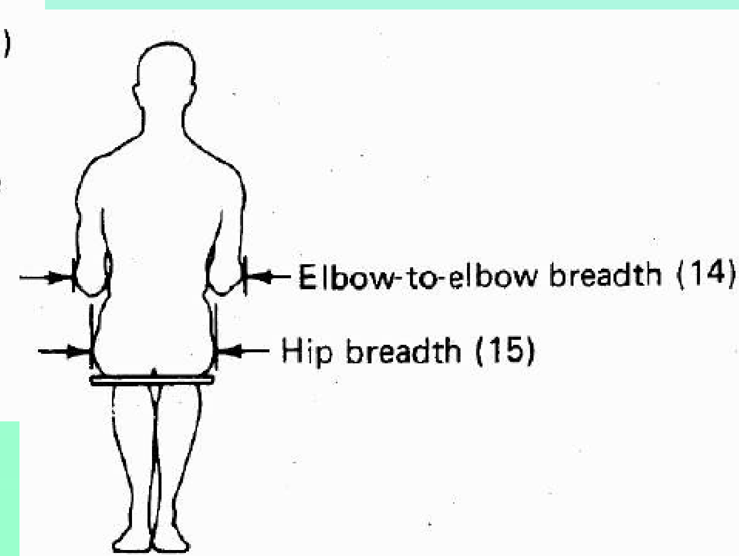
- Figure below: structural (static) body features

Notice: reference can be:

ground (1), or 2 body parts (11), or
ends of the same body part (9,13)







Cont. Anthropometry

Cont. Static Dimens.

- Table: selected body dimensions and weights of US adult civilians
- Dimensions 1-15 shown in last slide
- Questions:
  - How would this compare to Saudi body dimensions?
  - What factors affect these dimensions?
  - What is the meaning of “**percentile**”?

Body dimension	Sex	Dimension, in 5th	Dimension, in 50th	Dimension, in 95th	Dimension, cm 5th	Dimension, cm 50th	Dimension, cm 95th
1. Stature (height)	Male	63.7	68.3	72.6	161.8	173.6	184.4
	Female	58.9	63.2	67.4	149.5	160.5	171.3
2. Eye height	Male	59.5	63.9	68.0	151.1	162.4	172.7
	Female	54.4	58.6	62.7	138.3	148.9	159.3
3. Shoulder height	Male	52.1	56.2	60.0	132.3	142.8	152.4
	Female	47.7	51.6	55.9	121.1	131.1	141.9
4. Elbow height	Male	39.4	43.3	46.9	100.0	109.9	119.0
	Female	36.9	39.8	42.8	93.6	101.2	108.8
5. Knuckle height	Male	27.5	29.7	31.7	69.8	75.4	80.4
	Female	25.3	27.6	29.9	64.3	70.2	75.9
6. Height, sitting	Male	33.1	35.7	38.1	84.2	90.6	96.7
	Female	30.9	33.5	35.7	78.6	85.0	90.7
7. Eye height, sitting	Male	28.6	30.9	33.2	72.6	78.6	84.4
	Female	26.6	28.9	30.9	67.5	73.3	78.5
8. Elbow rest height, sitting	Male	7.5	9.6	11.6	19.0	24.3	29.4
	Female	7.1	9.2	11.1	18.1	23.3	28.1
9. Thigh clearance height	Male	4.5	5.7	7.0	11.4	14.4	17.7
	Female	4.2	5.4	6.9	10.6	13.7	17.5
10. Knee height, sitting	Male	19.4	21.4	23.3	49.3	54.3	59.3
	Female	17.8	19.6	21.5	45.2	49.8	54.5
11. Buttock-knee distance, sitting	Male	21.3	23.4	25.3	54.0	59.4	64.2
	Female	20.4	22.4	24.6	51.8	56.9	62.5
12. Popliteal height, sitting	Male	15.4	17.4	19.2	39.2	44.2	48.8
	Female	14.0	15.7	17.4	35.5	39.8	44.3
13. Chest depth	Male	8.4	9.5	10.9	21.4	24.2	27.6
	Female	8.4	9.5	11.7	21.4	24.2	29.7
14. Elbow-elbow breadth	Male	13.8	16.4	19.9	35.0	41.7	50.6
	Female	12.4	15.1	19.3	31.5	38.4	49.1
15. Hip breadth, sitting	Male	12.1	13.9	16.0	30.8	35.4	40.6
	Female	12.3	14.3	17.2	31.2	36.4	43.7
X. Weight (lbs and kg)	Male	123.6	162.8	213.6	56.2	74.0	97.1
	Female	101.6	134.4	197.8	46.2	61.1	89.9

Cont. Anthropometry

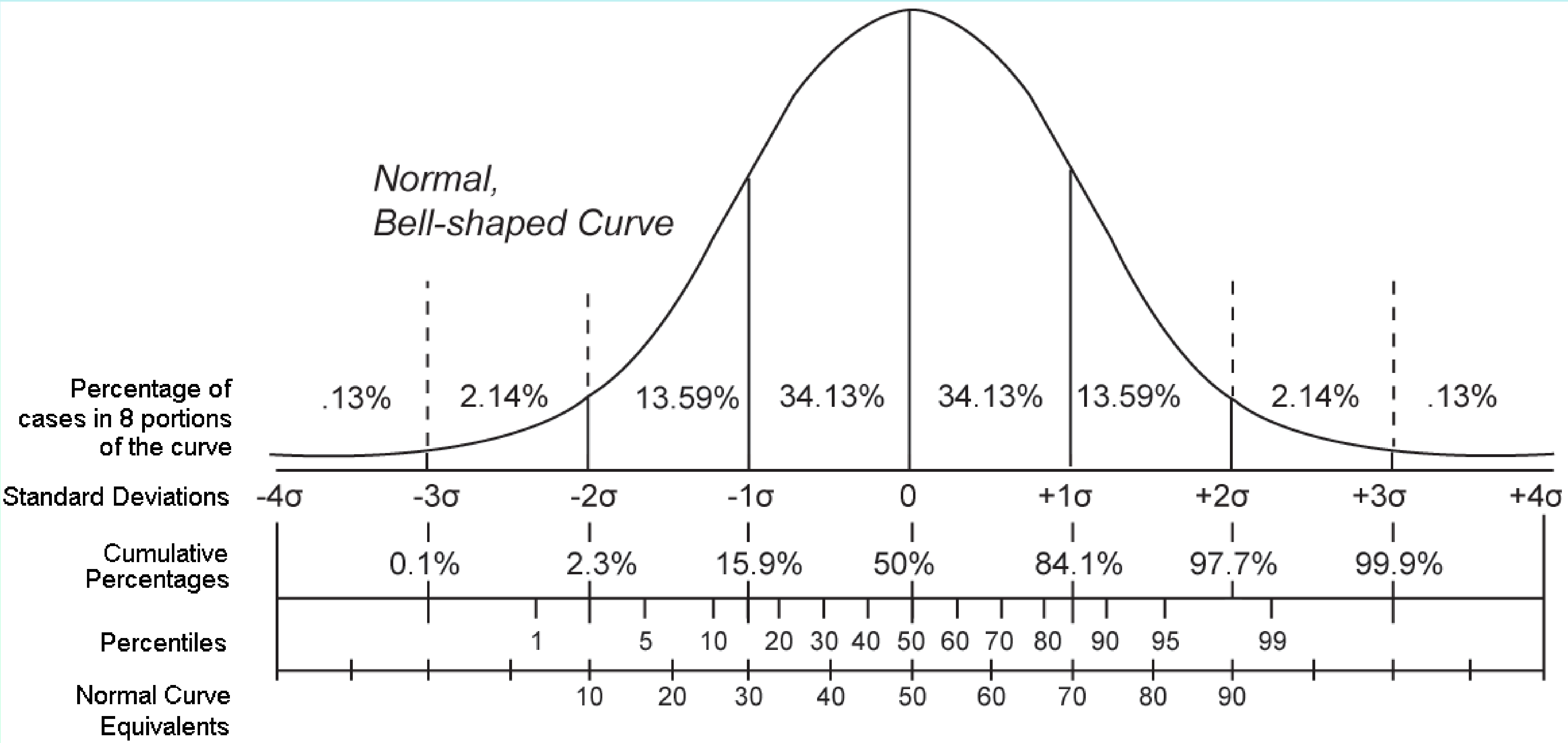
Cont. Static Dimensions

- Percentile :
  - Def^n:“a value on a scale of 100 that indicates the **percent** of a distribution that is **equal to or below it**”
  - Examples from last slide: male stature (which dim.?)
    - 5th percentile of standing males: 63.7 in (i.e. 162 cm) $\Rightarrow$ only 5% of males heights (US: 20–60) are $\leq$ 63.7 in
    - 50th percentile of male height: 68.3 in (i.e. 173 cm) $\Rightarrow$ 50% of males are shorter (or taller) than 68.3 in i.e. **median** of male heights (US: 20–60): 68.3 in (why?)
    - Q: what is 95 percentile of US male sitting height?
    - Q: what %ge of US females (20–60) weigh > 89.9 kg
  - **Interquartile range**
    - middle 50% of distribution: i.e. 25th – 75th percentiles
    - this is measure of variability

Cont. Anthropometry

Cont. Static Dimensions

- Cont. Percentile :
  - Figure below: percentiles in normal “bell” curve
  - Percentiles = sum of area (∫) under normal curve



Cont. Anthropometry

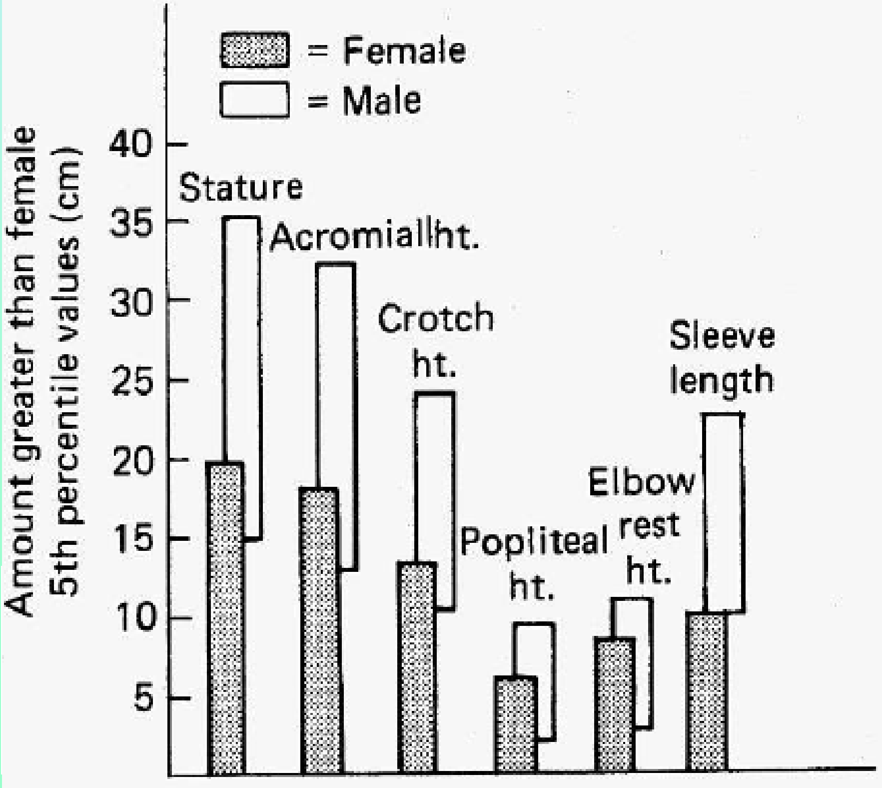
Cont. Static Dimensions

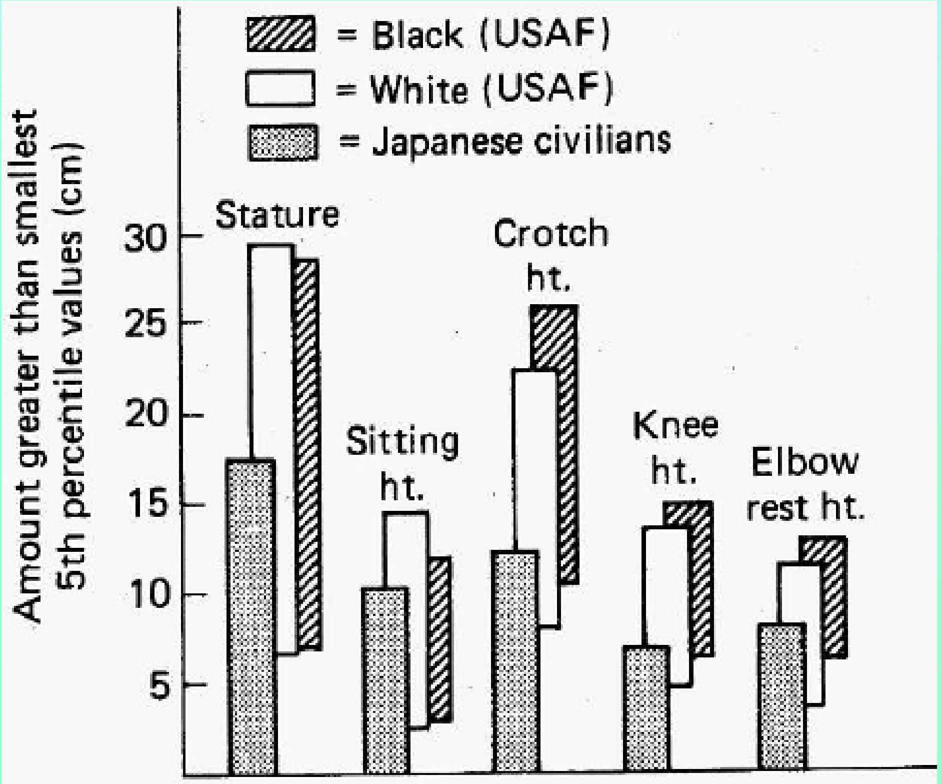
- Body dimensions vary with:
  - sex (males and females): next slide
  - ethnicity (whites, blacks, Asians, etc.): next slide
  - age:
    - generally lengths, heights ↑ until late teens/early 20's
    - then remain relatively constant through adulthood
    - then ↓: early-middle adulthood into old age
    - Did you know: exception is ear (continues all life long!)
  - occupation (i.e. job)
    - caused by:
      - imposed height and/or weight restrictions
      - physical activity involved in work
      - self-selection of applicants for practical reason (?)
    - e.g. truck drivers: taller, heavier > general population
  - times: US, Eur. ht. ↑ 1 cm/decade:1880-1960 (?)

Cont. Anthropometry

Cont. Static Dimensions

- Cont. Body dimensions variations:
  - **Sex** (left figure): comparison showing overlap in male 5th %ile with female 95th %ile heights (huge!)
  - **Ethnicity**: (right figure): comparison showing 5th–95th %ile among different male heights





Cont. Anthropometry

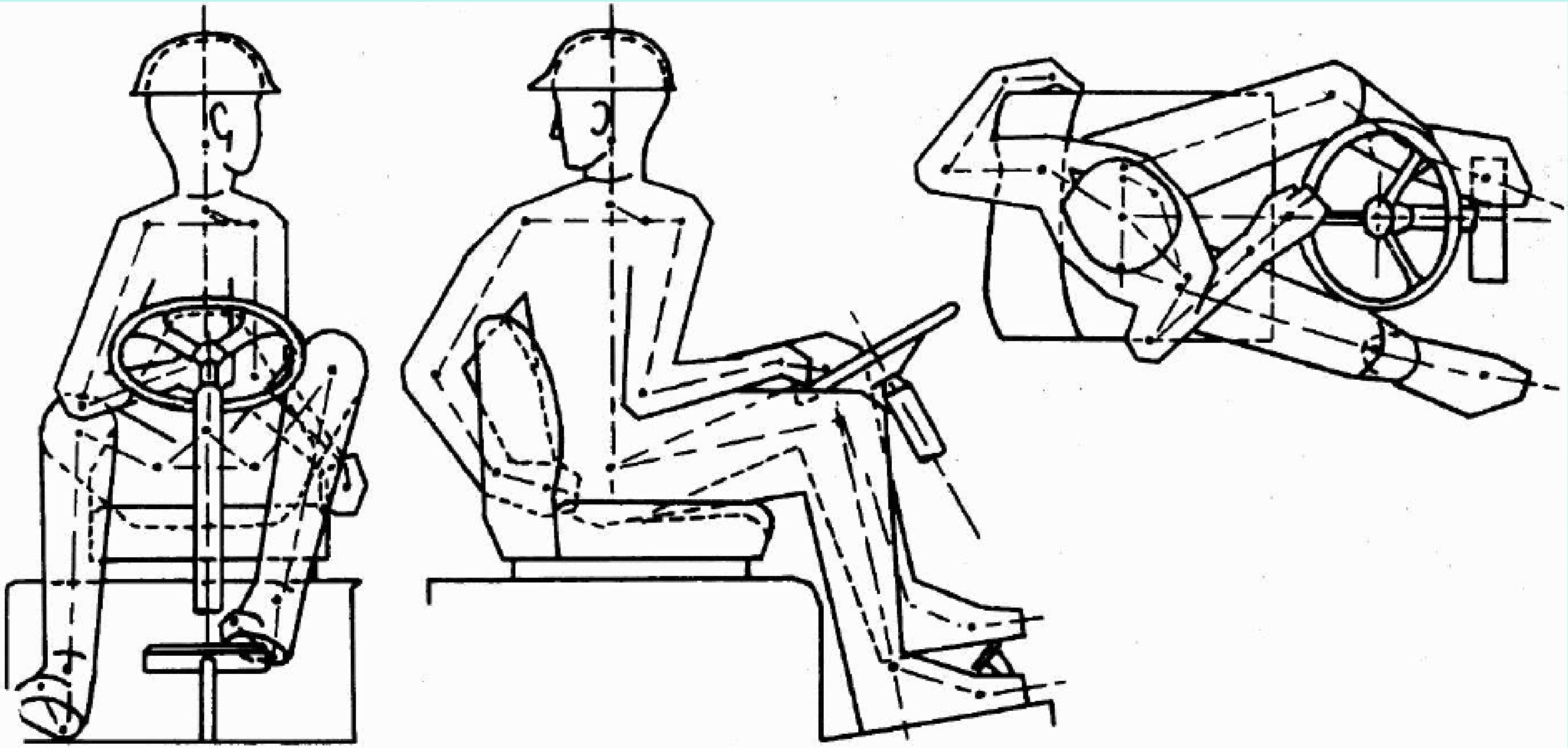
Dynamic (Functional) Dimensions

- Def^n: measurements taken while body is engaged in some physical activity; e.g.
  - operating a steering wheel
  - assembling a toy
  - reaching across the table for salt, etc.
- Individual body members function mostly in concert
  - i.e. all parts are affected together, at the same time
  - e.g. limit of arm reach involves
    - arm length, but also:
    - shoulder movement
    - trunk rotation (possible)
    - back bending (possible)
    - hand function

Cont. Anthropometry

Cont. Dynamic (Functional) Dimensions

- **Somatography**: diagram showing interaction of various body members
  - e.g. below: 3 views (front, side, top) for forklift truck operator



Cont. Anthropometry

Discussion: Static, Dynamic Dimensions

- Anthropometric data
  - Static data exists » dynamic data
  - However, dynamic data: more representative of actual human activity
- Converting static data to dynamic data
  - No systematic procedure available
  - However, following recommendations are helpful:
    - Heights (stature, eye, shoulder, hip): reduce by 3%
    - Elbow height: no change, or ↑ by 5% if elevated at work
    - Knee or popliteal height, sitting: no change, except with high-heel shoes
    - Forward and lateral reaches:
      - ↓ by 30 percent for convenience
      - ↑ by 20 percent for extensive shoulder and trunk motions
    - Note, these estimates may change: e.g. work condition

Use of Anthropometric Data

- Which anthropometric data to use?
  - Data should be representative of population that would use the designed item
  - If designing for “everyone”⇒ the design features must accommodate as many people as possible
  - If designing for specific groups ⇒ use data for your specific groups; examples:
    - adult females
    - children
    - elderly (seniors)
    - soccer players
    - the handicapped (can you name more examples?)
    - Note, many specific groups do not yet have available anthropometric data

Use of Anthropometric Data

Principles in Application of Anthropometric Data

- Three general principles
- Each applies to different situation:
  1. Designing for **Extreme Individuals**
  2. Designing for **Adjustable Range**
  3. Designing for the **Average**

Use of Anthropometric Data

Cont. Principles in Appl. of Anthropometric Data

1. Designing for Extreme Individuals:
   - designs should *try* to accommodate everyone
   - a single design dimension can be:
     - limiting factor restricting use of facility for some
     - a dictate for max./min. value of variable in question
   - designing for **max. population** value:
     - used if given max/high value of some design feature should accommodate -almost- all people
     - examples: heights of doorways, strength of supporting devices (e.g. rope ladder, workbench, trapeze)
   - designing for **min. population** value:
     - used if given min/low value of some design feature should accommodate -almost- all people
     - examples: distance of control button from operator; force required to operate the control

Use of Anthropometric Data

Cont. Principles in Appl. of Anthropometric Data

2. Designing for Adjustable Range:
   - equipment/facilities can have design features: adjustable to individuals who use them
     - e.g.'s: automobile seats, office chairs, foot rests
   - adjustments (e.g. arm reach) usu. cover range: **5th female – 95th male** %tile of pop. characteristic
     - ⇒ covers **95%** (not 90%) of 50/50 male/female pop. (??)
     - used when hard to cover extreme cases (100% of pop) due to resulting technical difficulties involved
   - designing for adjustable range: **preferred method** of design, but is not always possible (why?)

Use of Anthropometric Data

Cont. Principles in Appl. of Anthropometric Data

3. Designing for the Average
   - Designing for average generally not preferred:
     - it should not just be “quick, easy way out” for design
     - there is no “average” person
     - person may be average on 1-2 dimensions but almost impossible on more than that:
       - no perfect correlation exists between body dimensions
       - e.g. people with short arms don’t have to have short legs
   - When it is ok to design for average:
     - in situations involving **non-critical** work (?)
     - when not appropriate to design for extreme cases
     - where adjustability is impractical
     - e.g.: checkout counter at supermarket built for the average customer

Use of Anthropometric Data

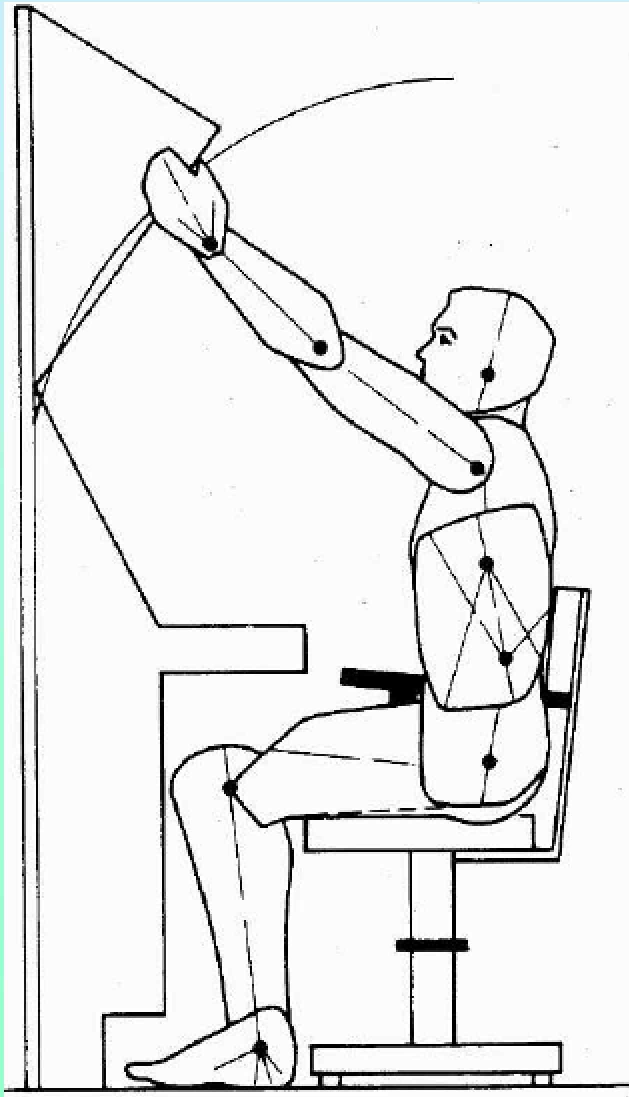
Cont. Principles in Appl. of Anthropometric Data

- Discussion of Anthrop. Design Principle
  - above principles apply to only single dimension
    - e.g. arm reach (only), or stature height (only)
  - considering > 1 dimension may cause “problems”
    - taking 5^{th} – 95^{th} %ile on >1 dimension
      ⇒ eliminates high %ge of population
      - on 13 dimen. ⇒ eliminates 52% (not just 10%) (*Bittner, ’74*)
      - why? no perfect correlation exists bet. body dimensions
      - ⇒imp. to consider body dimension *combinations* in design
    - adding 5^{th} or 95^{th} %ile of body segments ≠ corresponding %ile value for combined dimension
      - e.g. lengths: fingertip to elbow + elbow to shoulder ≠ fingertip to shoulder
      - why? (again): no perfect correlation bet. body dimensions
      - building 5^{th} %ile female (ankle height, ankle to crotch, etc.) ⇒ female is 6 in (15.6 cm) < actual 5^{th} %ile stature!

Use of Anthropometric Data

Cont. Principles in Appl. of Anthropometric Data

- Cont. Discussion of Anthrop. Design Principle
  - articulated models
    - AKA: articulated anthropometric scale models
    - physical models (i.e. full-scale mockup)
    - represent specific population %ile
    - usu. used with work-space design (see right)
    - note, computer software also exists to model work-space design



Use of Anthropometric Data

Cont. Principles in Appl. of Anthropometric Data

- Suggested Procedure for Using Anth. Data
  1. Determine body dimensions important in design
     - e.g. application: sitting height or stature height?
  2. Define population to use facility/equipment
     - establishes dimensional range to be considered
     - e.g. children, women, Saudi men, world population)
  3. Determine principle to be applied
     - i.e. extreme individuals, adjustable range, average?
  4. Select %ge of pop. to be accommodated (e.g. 90%)
  5. Find appropriate anthropometric data tables for chosen population used, extract relevant values
  6. Add appropriate allowances (e.g. clothing, shoes)
  7. Build full-scale mock-up of facility/equipment, have representative people of large and small users (of the population) test it (very important!)