Anthropometry

- Agenda
  - Review
  - Anthropometry
How to Design a Study

❖ Within-Subjects
  - Independent variable manipulated within a single subject
  - Each subject exposed to all treatment levels
  - Repeated measures; “treatment x subject”

❖ Between-Subjects
  - Independent variable manipulated between \( n \geq 2 \) subjects
  - Each subject exposed to only one treatment level
  - “Separate groups”

<table>
<thead>
<tr>
<th>Within-Subject</th>
<th>Between-Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent Variable</td>
<td>Independent Variable</td>
</tr>
<tr>
<td>Level 1</td>
<td>Level 2</td>
</tr>
<tr>
<td>P 1</td>
<td>P 1</td>
</tr>
<tr>
<td>P 2</td>
<td>P 2</td>
</tr>
<tr>
<td>P 3</td>
<td>P 3</td>
</tr>
</tbody>
</table>
# How to Design a Study

<table>
<thead>
<tr>
<th></th>
<th>Within</th>
<th>Between</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td>Fewer Participants</td>
<td>No transfer effects between conditions</td>
</tr>
<tr>
<td></td>
<td>Shorter experimental time (for experimenter)</td>
<td>No need for counterbalancing</td>
</tr>
<tr>
<td></td>
<td>Smaller variability between groups</td>
<td>Matching can reduce inter-group variability</td>
</tr>
<tr>
<td></td>
<td>Need to counterbalance</td>
<td>Random assignment eliminates bias</td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
<td>Learning effect</td>
<td>Possible inter-group differences</td>
</tr>
<tr>
<td></td>
<td>Possible transfer between conditions</td>
<td>More participants required</td>
</tr>
<tr>
<td></td>
<td>ABBA counterbalancing assumes linear confounding effects</td>
<td>More experimental time (for experimenter)</td>
</tr>
<tr>
<td></td>
<td>All counterbalancing assumes symmetrical transfer</td>
<td>Matching takes effort and assumes no transfer from matching operations</td>
</tr>
<tr>
<td></td>
<td>Range effects may be problematic</td>
<td></td>
</tr>
</tbody>
</table>

From: Martin (2008) Table 8-7
Anthropometry

- Definition
  - Greek
    - “Anthropos”: “man”
    - “Metreo”: “to measure”
  - Detailed Definition
    - A scientific discipline provides the fundamental basis and quantitative data for matching the physical dimensions of workplaces and products with the body dimensions of intended users
Anthropometry

- Engineering anthropometry originated from anthropology, and seeks to describe the physical dimensions of the (human) body.

- Engineering anthropometry as applied to ergonomics and biomechanics can be separated into:
  - **Physical (Structural/Static) anthropometry:** addresses fundamental physical dimensions of the body.
  - **Functional (Dynamic) anthropometry:** physical dimensions relevant to completing particular activities or tasks.
  - Develop functional design data from physical data.
Anthropometry

- Static anthropometry
  - Weight and volume
  - Segment length and circumference
  - Shape
  - Center of mass (center of gravity)
    - A point at which body’s mass behaves as if it were concentrated.
    - Function of the positions and masses of the body segments.
Anthropometry

Static anthropometry

- Center of mass (center of gravity)
  - Use of COM in biomechanical calculations
    - E.g., External elbow moment due to weights of forearm/hand and tool
  - Requires knowing where the mass (weight) is located
  - Mass represented at a specific location = COM
Anthropometry

- Measurement Tools
  - Anthropometer, measuring tape, scale, grid system
  - Simple but time consuming! (Very specific guidelines for use)
Anthropometry

Measurement Tools

Anthropometry

Measurement
- To obtain meaningful dimensions, extreme care must be taken to
  o Specify exactly what is being measured and how
  o Dimensions must be located relative to physical (anatomical)
    landmarks (common to all people and easy to locate) on the body
  o Example: Hand breadth

61 HAND BREADTH: The breadth of the hand between the second and the fifth metacarpal-phalangeal joints.
Anthropometry

- Landmarks of the human body
  - Anatomical Landmark: an anatomic structure used as a point of reference in establishing the anatomic relationships
Functional anthropometry

Spatial information for specific activities
- Measures are influenced by specific tasks and/or individual performance

Range of motion
- Limited by body tissues such as bones, ligaments, muscle-tendon units, and other body parts.
- Affected by age, gender, time of day, warm-up, segment length.
Anthropometry

- Body Planes
Standard terminology (Describe the relative positions of the body parts)

- **Midline**: An imaginary line that divides the body into right and left halves
- **Medial**: Toward the midline that divides left and right
- **Lateral**: To the side away from the midline
- **Proximal**: Closer to the torso, e.g. shoulder
- **Distal**: Farther away from the torso, e.g. elbow
- **Superior**: Toward the head
- **Inferior**: Away from the head
- **Anterior**: The front of the body or body part
- **Posterior**: The back of the body or body part
Body Movement

Flexion v.s. Extension

- Flexion: Bending movement that decreases the angle between two parts.
- Extension: Straightening movement that increases the angle between two parts.
Anthropometry

- Body Movement

  - Wrists/Hands
    - Flexion - Bending
    - Extension - Extending, straightening
Body Movement

- Adduction vs. Abduction
  - Adduction: motion that pulls a segment toward the midline of the body.
  - Abduction: motion that pulls a segment away from the midline of the body.
Anthropometry

- Body Movement
  - Radial deviation/ulnar deviation

![Diagram of hand movements showing radial deviation and ulnar deviation](image-url)
Body Movement

- Pronation vs. Supination
  - Pronation: rotation downwards (palm facing down; sole facing laterally)
  - Supination: rotation upwards (palm facing up; sole facing medially)

http://run360run.blogspot.com/2012_09_01_archive.html
Variability

- Class Demonstration
  - Height

- Source of variability
  - Measurement variability
  - Inter-subject variability
    ✓ The variability between people.
    ✓ The most important for most applications of anthropometry
  - Intra-subject variability
    ✓ The variability within a person
    ✓ Over years; within a day; transient

Anthropometry Variances
- Height
- Size
- Weight
- Body segment proportion

Population Variances
- Gender
- Age
- Sex
- Racial/Ethnic
- Occupational
- Generational
- Transient Diurnal
Anthropometry

How to Minimize the Variability

- Measure twice or more
- Be specific in description
- Consider purpose for data collection
  - What to collect, how to interpret, how to use
- Consider
  - Time of day
  - Accuracy/precision of instrument
  - Bony landmarks vs. soft tissue landmarks
Anthropometry

Statistics for Anthropometry

- Normal distribution approximation
  - Compute mean & standard deviation.
  - Assume normal distribution (no skewness).
Anthropometry

Statistics for Anthropometry

- Normal distribution approximation

Example

- Study the heights of adults, ages 18-24 in USA
- Target population:
  - Women (1000 subjects)
    - mean: 65.0 inches
    - standard deviation: 2.5 inches
  - Men (1000 subjects)
    - mean: 70.0 inches
    - standard deviation: 2.8 inches
Statistics for Anthropometry

- Normal distribution approximation
- Example
  - Study the heights of adults, ages 18-24 in USA
    - Women
      - 68% are between 62.5 and 67.5 inches
        \[\text{mean } \pm 1 \text{ sd } = 65.0 \pm 2.5\]
      - 95% are between 60.0 and 70.0 inches
      - 99.7% are between 57.5 and 72.5 inches
    - Men
      - 68% are between 67.2 and 72.8 inches
        \[\text{mean } \pm 1 \text{ sd } = 70.0 \pm 2.8\]
      - 95% are between 64.4 and 75.6 inches
      - 99.7% are between 61.6 and 78.4 inches
Statistics for Anthropometry

- Normal distribution approximation

- Example
  - What proportion of men are less than 72.8 inches tall? Given mean=70, SD=2.8

  - 72.8 inches → %ile?
  - 72.8 inches → %ile?
  - ≈34%

  - Mean
  - 70
  - 72.8

  - Standard Deviations:
    - 0 SD
    - 1 SD
    - 2 SD
    - 3 SD

  - Height in inches:
    - 61.6
    - 64.4
    - 67.2
    - 70
    - 72.8
    - 75.6
    - 78.4

  - = 50% + 34% = 84%ile
Statistics for Anthropometry

Percentile Value

- A percentile value of an anthropometric dimension represents the percentage of the population with a body dimension of a certain size or smaller.
  - For example, 99th percentile value of stature means 99% of the individuals in that population would be equal or shorter than that value.
- Percentiles can easily be calculated from mean and standard deviation from population anthropometric data:
  - Percentile Value = mean + z*SD (z: z score from Z-tables)
## Anthropometry

### Selected Structural Body Dimensions and Weights of Adults

<table>
<thead>
<tr>
<th>Body Feature</th>
<th>Dimension, in</th>
<th>Male, percentile</th>
<th>Female, percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5th</td>
<td>50th</td>
</tr>
<tr>
<td>1 Height</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Sitting height, erect</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Sitting height, normal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Knee height</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Popliteal height</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Elbow-rest height</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Thigh-clearance height</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 Buttock-knee length</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 Buttock-popliteal height</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Elbow-to-elbow breadth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 Seat breadth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 Weight</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Weight given in pounds

Source: U.S. Public Health Service, 1965
Statistics for Anthropometry

Percentile Value

Example

Assume height (stature) of OSU students: Mean = 168.0 cm, SD = 8.6 cm.

Q1: What is the height of the 98th percentile of this population?
Percentile value = mean + z*SD
98th percentile = 168.0 cm + 2.05 * 8.6 cm = 185.6 cm

Q2: Assume your height is 175 cm. If there are 1,000 OSU students currently registered, how many would you expect to taller than you?

175 cm = 168 cm + Z*8.6
Z ≈ 0.81
Using z-table, Φ(z) = 79%
1000 * (1 - 0.79) = 210 students
Anthropometry

- Use of anthropometric data
  - Workplace design (reach, clearance, functional ability, postural support, vision, comfort)
  - Tool design (size, shape, weight)
  - Biomechanical models
    - Scale of human stature
    - Define body range of motion
    - Strength
Anthropometry

Use of anthropometric data

- Product design
  - Design principles
    - Design for clearance/accommodation
      - Design for the large person (Let the large person fit.)
    - Design for reach / accessibility
      - Design for the small person (Let the small person reach.)
    - Design for adjustability
      - Design for everyone
    - Design for the average person
Use of anthropometric data

- Product design
  - Design for Clearance/Accommodation
    - Design for the Large Person (Let the large person fit.)
Anthropometry

- Use of anthropometric data
  - Product design
    - Design for Reach / Accessibility
      - Design for the Small Person (Let the small person reach.)
Anthropometry

- Use of anthropometric data
  - Product design
    - Design for Adjustability
    - Design for Everyone
Anthropometry

- Use of anthropometric data
  - Product design
    - Design for the average person
Anthropometry

- Use of anthropometric data
  - Biomechanical model
    - Based on your **stature**, calculate the **length** of your upper arm, forearm, and hand.
    - Based on the **mass** and **length** data of your arm segments, calculate the **location of center of mass** of your arm (distance from shoulder).
Anthropometry

Use of anthropometric data

- Biomechanical model

<table>
<thead>
<tr>
<th>TABLE 3.7 Recommended Link Length as Proportion of Stature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length Fraction of Stature</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Wrist to finger tip</td>
</tr>
<tr>
<td>Forearm</td>
</tr>
<tr>
<td>Upper arm</td>
</tr>
<tr>
<td>Head</td>
</tr>
<tr>
<td>Neck</td>
</tr>
<tr>
<td>Head and neck</td>
</tr>
<tr>
<td>C7T1 to SCJ</td>
</tr>
<tr>
<td>L5S1 to shoulder center</td>
</tr>
<tr>
<td>L5S1 to hip center</td>
</tr>
<tr>
<td>Upper leg</td>
</tr>
<tr>
<td>Lower leg</td>
</tr>
<tr>
<td>Shoulder width</td>
</tr>
<tr>
<td>Hip width (between joint centers)</td>
</tr>
<tr>
<td>Foot width</td>
</tr>
<tr>
<td>Heel to toe</td>
</tr>
<tr>
<td>Ankle height</td>
</tr>
</tbody>
</table>

Figure 3.10. Link boundaries and locations of center of mass as a percentage of link lengths (Dempster, 1955).
Use of anthropometric data

Biomechanical model

- Example: Given, your stature=180 cm. What is the distance of your upper arm COM from your elbow

  ✓ Male
  - Length of Upper Arm=180 cm * 0.1877 = 33.9 cm
  - Distance = 33.9 cm * 0.564 = 19.1196 cm

  ✓ Female
  - Length of Upper Arm=180 cm * 0.1843 = 33.2 cm
  - Distance = 33.2 cm * 0.564 = 18.7248 cm