Workstation Design

- Agenda
  - Review
  - Functional Anthropometry and Design
  - Workstation Design

Review

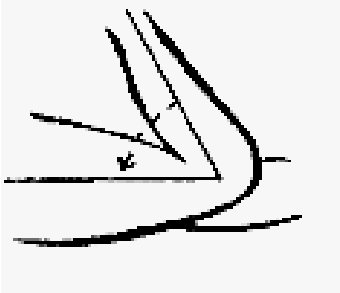
- Anthropometric Data
- Structural Data: Static
  - Segment length or link length
  - Segment density
  - Mass
  - Center-of-mass location

- Functional Data: Dynamic
  - Reach envelop (e.g. could be arm plus extended torso)

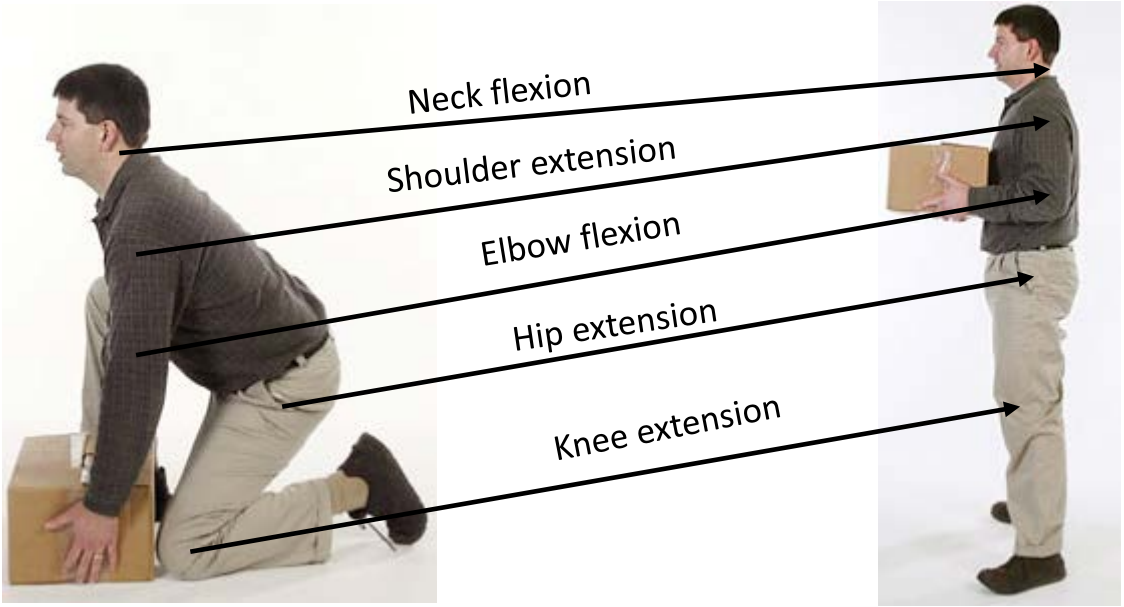
Review

- Name the following movements

Knee flexion



Knee flexion

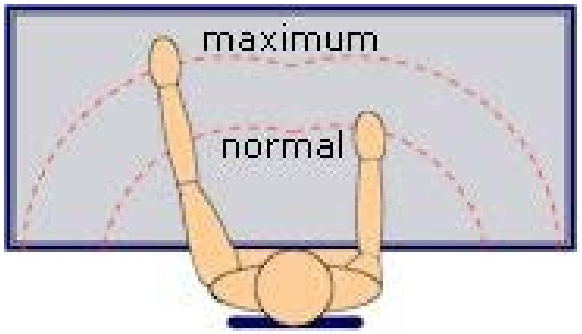


Review

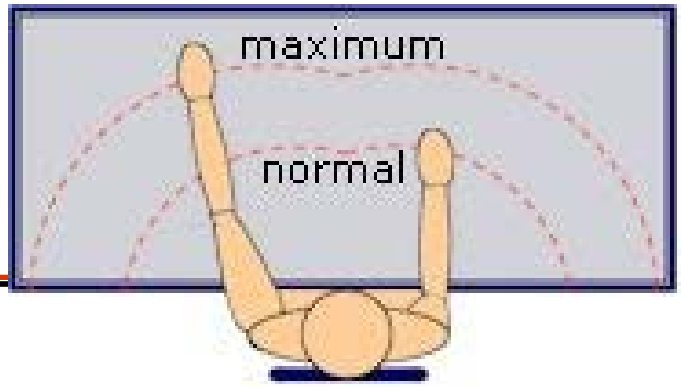
- Use anthropometric data for design
  - When designing the public wash basin height
    - Can’t accommodate all users (kids vs. adults)
    - Ideally design for different age group (multiple dimensions to accommodate)

Functional Anthropometry and Design

- Measure functional anthropometry
  - Reach envelop
    - Reach envelops need to be constructed for actual working positions and for explicit design purposes.
      - ✓ Dependent on the task, motion, and function to be accomplished by the reach action.
    - Limited reach data on standard anthropometric positions are available in sources of static and dynamic anthropometric data.
      - ✓ Task specific
    - Reach envelops may be related to a body reference point (e.g., the shoulder joint), or to a design point (e.g., a seat reference point).



Functional Anthropometry and



❖ Example

- Horizontal reach envelop for seated workstation design
  - o <u>Seated Arm Horizontal Reach envelops (Normal)</u>:
    - ✓ The shoulders are relaxed,
    - ✓ the test upper arm is approximately vertical (90° at elbow),
    - ✓ the elbows are held loosely against the torso with no more than 20 degrees abduction.
    - ✓ The normal reach envelop could be measured by sweeping only the forearm from left to right with upper arm vertically located.
    - ✓ At least 5 positions (left→right) should be recorded to draw the envelop
  - o <u>Seated Arm Horizontal Reach envelops (Maximum):</u>
    - ✓ Measured similarly to normal reach, except that
      - the test arm is held straight forward
      - and the test <u>shoulder is extended forward as far as</u> possible while the other shoulder is kept still

Functional Anthropometry and Design

- Range of motion

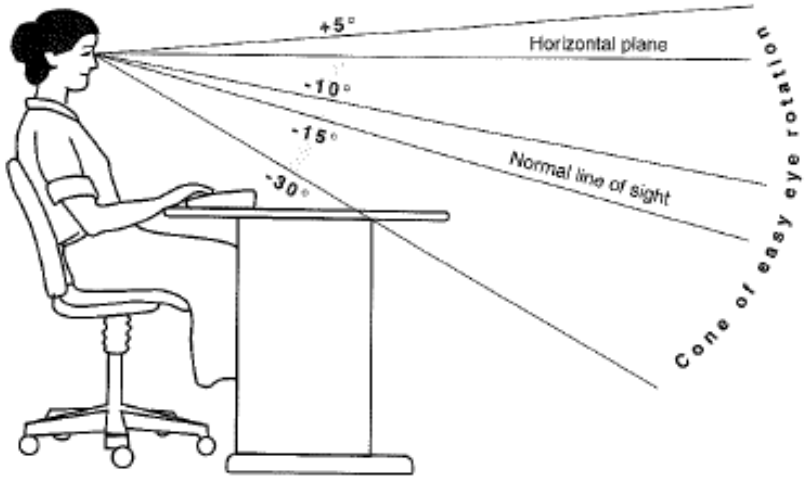
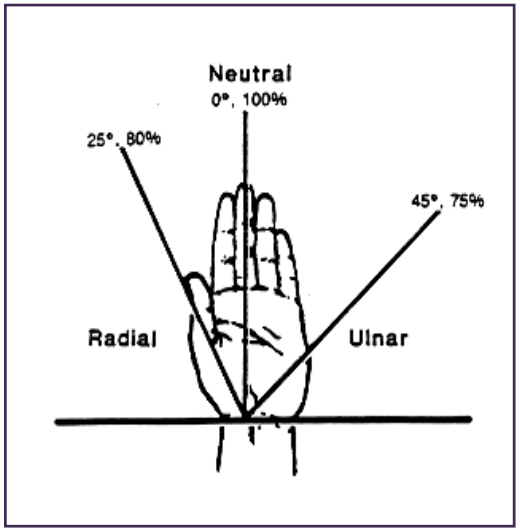
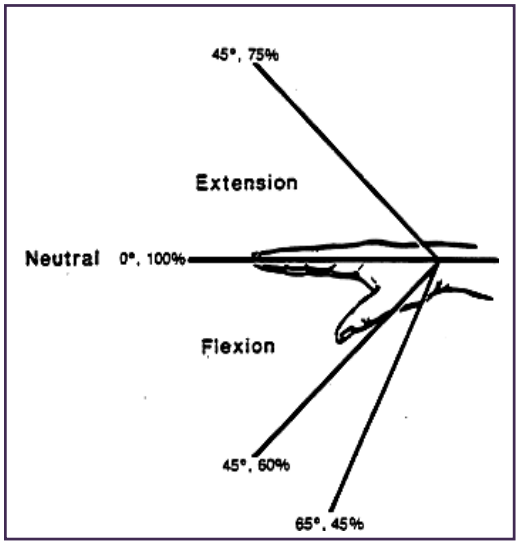


FIGURE 10.6
The normal line of sight and the range of easy eye rotation. (*Source:* Grandjean, E., 1988. *Fitting the Task to the Man* (4th ed.). London: Taylor and Francis. Reprinted by permission of Taylor and Francis.)

Functional Anthropometry

- Posture vs. Strength
  - Neutral Posture
    - The resting position of each joint-the position in which there is the least tension or pressure on nerves, tendons, muscles and bones.
    - It is also the position in which muscles are at their resting length-neither contracted nor stretched.
      - ✓ Muscles at this length can develop maximum force most efficiently.
    - Example
      - ✓ Hand posture on grip strength





Workstation Design

The **Emperor 200**... Luxury, Sophistication and Ergonomic Comfort without Compromise.

Workstation Design

Workstation Design

Workstation Design

Workstation Design

Workstation Design

Workstation Design

- Workstation Components
  - Enclosure (e.g., cab)
  - Doors / doorways
  - Windows
  - Seats / supports
  - Lighting fixtures
  - Heating, ventilating, and air conditioning equipment
  - Life support equipment
  - Material handling equipment (in, within, out)
  - Storage facilities
  - Work surfaces
  - Tools
  - Materials
  - Fixtures, work holding devices
  - Displays
  - Controls
  - Computers and other electronics
  - Reference materials
  - Communication equipment
  - Personal protective equipment
  - Personal items

Workstation Design

- Goals of Ergonomic Workstation Design and Layout
  - Maximize performance and minimize hazards
    - Accommodate the worker
      - ✓ An uncomfortable workstation results in increased energy demands, fatigue, decreased worker performance, and occupational injuries
    - Minimize postural stress and fatigue (e.g. due to static loading)
      - ✓ Risk factor for work-related injury
    - Provide reach capability
      - ✓ Anthropometry
    - Minimize motion times and error rates
      - ✓ Work measurement (e.g. time increase 30% when working overhead)
    - Provide force capability
      - ✓ strength data and models

Workstation Design

- Common Risk Factors
  - Awkward postures
    - Maintaining an unsupported fixed or awkward posture such as bending, reaching, or twisting
  - Over exertion
    - Above maximum limits
  - Repetition, Vibration
  - Static loading
  - Environmental (heat, cold, poison, etc)

Workstation Design

- Workstation Types
  - Sit
  - Sit/Stand
  - Stand

Workstation Design

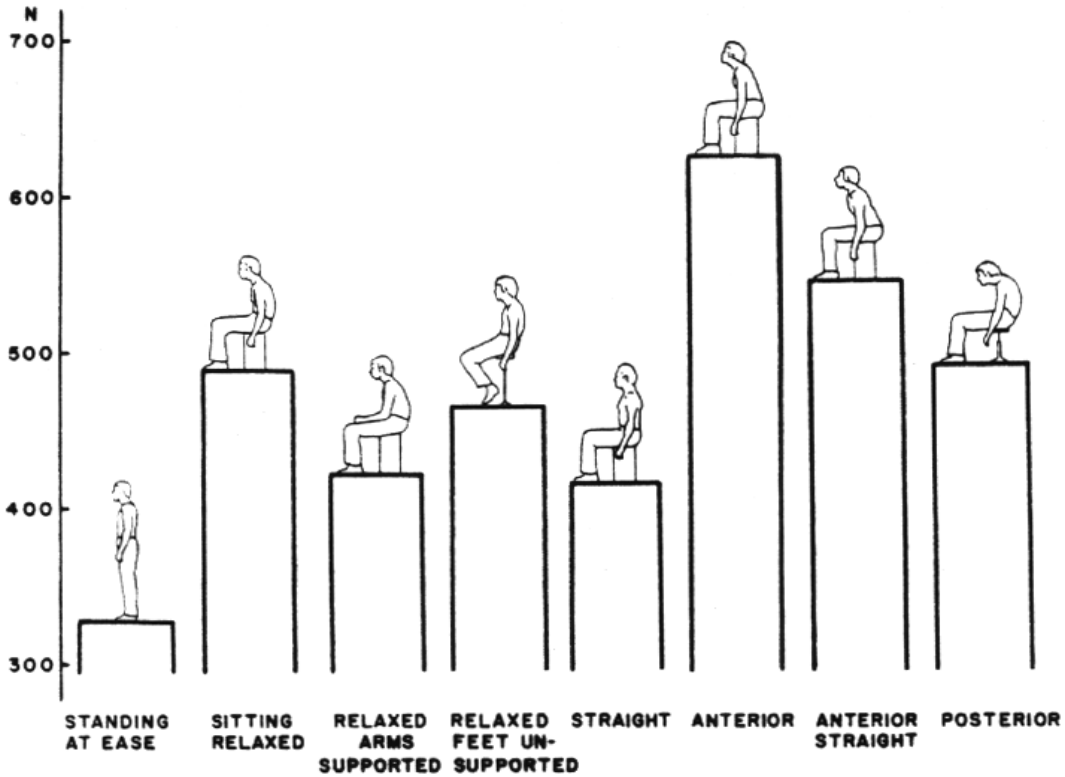
- Pros and Cons of Seated Work
  - Advantages of seated postures:
    - Greater stability for tasks requiring high visual and motor control
    - Less energy consumption
    - Less stress on the lower extremities
    - Delays the onset of fatigue (weight is taken off the legs, lower energy requirements, lower cardio-respiratory demands, avoid unnatural body postures)
    - Allows for the use of foot controls
  - Disadvantages of seated postures:
    - Pitfalls of prolonged sitting
      - ✓ Negative effects on the curvature of the spine
      - ✓ Disruption of body functions (blood flow, breathing, etc.)
      - ✓ Weakened abdominal muscles

Workstation Design

- Pros and Cons of Seated Work
  - Disadvantages of seated postures:
    - Example

i. Disc force (pressure) is lower in relaxed standing

ii. Forces are higher in any unsupported sitting posture (≥2x)



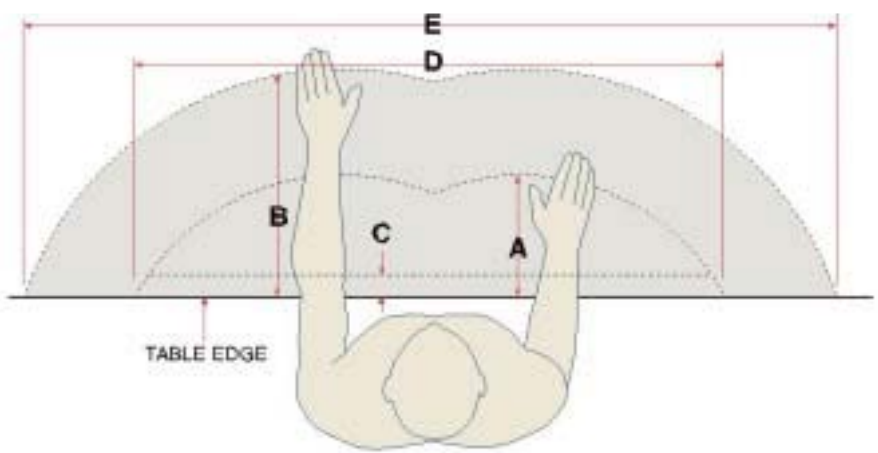
Disc pressure measurements in standing and unsupported sitting postures (Chaffin et al, 2006)

Workstation Design

- Pros and Cons of Seated Work
  - Trade-off considerations
    - Duration for each tasks, majority of tasks takes precedence
    - Optimize extended reaches and exertion forces
  - **Sit when**
    - Fine assembly, data entry, precise control, etc.
    - Needed items can be reached, assessed, and handled within the seated workstation.
      - ✓ Reach envelop
    - Items handled are approximately 6” above and 16” in front of the worker
    - No large forces, no weights greater than 10lbs

Workstation Design

- Seating Design Measurements – Work Surface Depth
  - HORIZONTAL work surface depth
    - Normal area: a sweep of the forearm while the upper arm hangs in a natural position
    - Max area: reached by extending the arm from the shoulder
    - These functional anthropometric dimensions are used to determine the placement of switches and controls
      - ✓ E.g., Car interiors panel



Criteria	Dimension
A. Normal Reach	Max. 12" (30 cm)
B. Extended Reach	Max. 18" (46 cm)
C. Work Distance	1 – 4" (2.5 – 10 cm)
D. Normal Reach Width	Max. 40" (102 cm)
E. Extended Reach Width	Max. 60" (152 cm)

Workstation Design

- Pros and Cons of Standing Work
  - Advantages of standing postures:
    - Greater Reach Capacity (larger work envelop)
    - Biomechanical Advantage (more leverage)
    - Lower Disc Pressure (only when not flexed)
    - Close to neural posture, e.g., spine
    - Increased Trunk Power (we can work harder)
    - Less Leg Room Required (horizontally)

Workstation Design

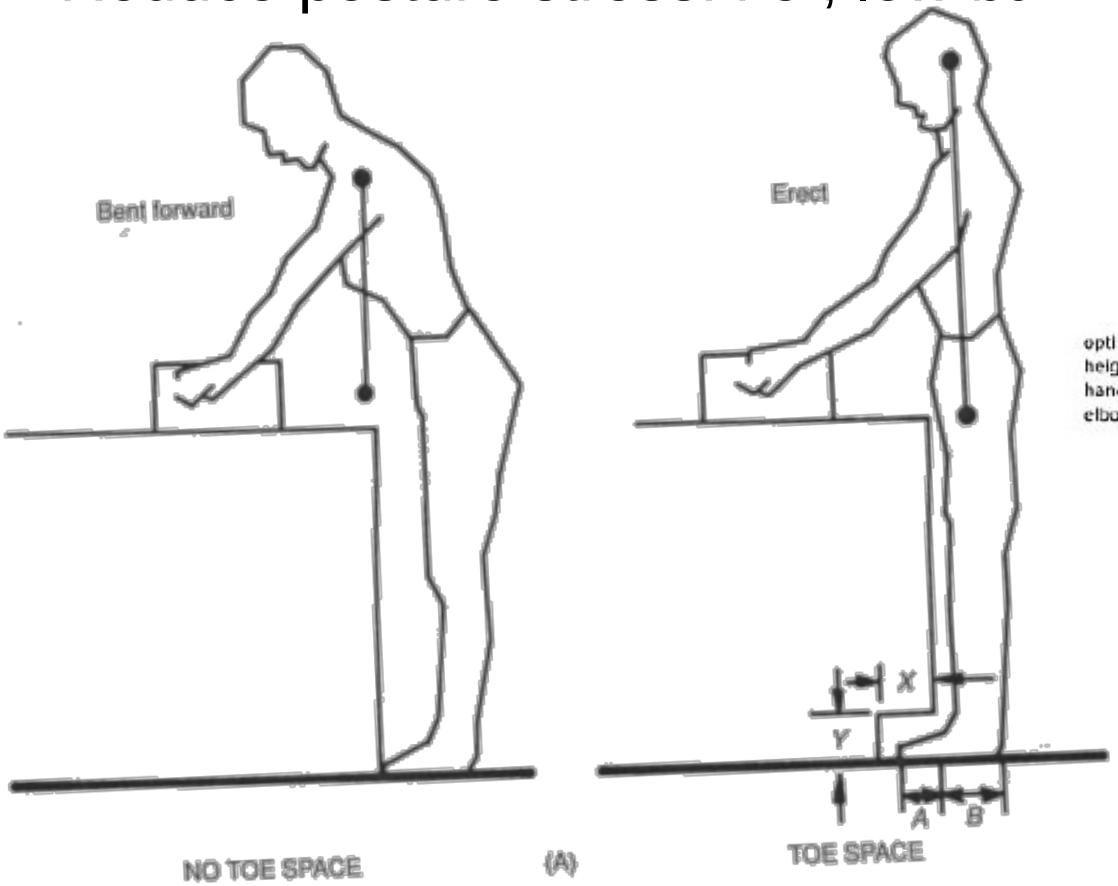
- Pros and Cons of Standing Work
  - Disadvantages of standing postures:
    - Facilitates Greater Postural Stress
      - ✓ Greater reach capacity (larger work envelop)
      - ✓ Working height of the hands is too high: Extension in the low back (excessive lordosis)
      - ✓ Work Surface is too low: Trunk flexion, back muscle strain
      - ✓ Lack of Toe Clearance: Increase horizontal distance (moment arm)
      - ✓ Asymmetric or “Non-neutral” postural constraints: Eliminate fixity, if no, then make work posture as natural as possible
      - ✓ Asymmetrical loading/Working away from the midline of the body: Twisting makes the spine more prone to injury

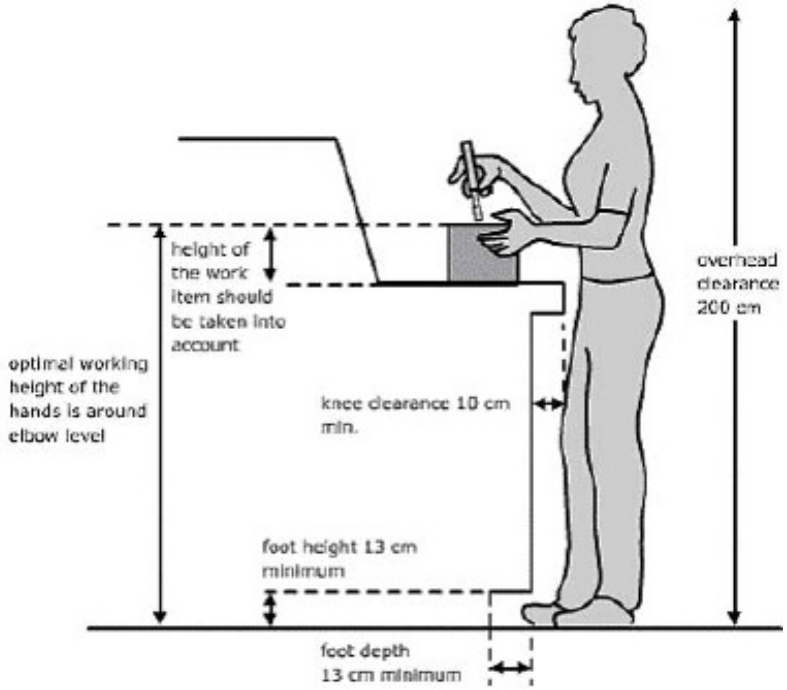
Workstation Design

- Pros and Cons of Standing Work
  - Disadvantages of standing postures:
    - Facilitates Greater Task Stress
      - ✓ Because biomechanical advantage (more leverage)
      - ✓ We have a greater work capacity when standing
        - Leaves the opportunity for greater task demand: Fatigue, High Joint Loads, Less support

Workstation Design

- Reduce posture stress: i.e., low back loads





Workstation Design

- Work Height vs Work Surface Height

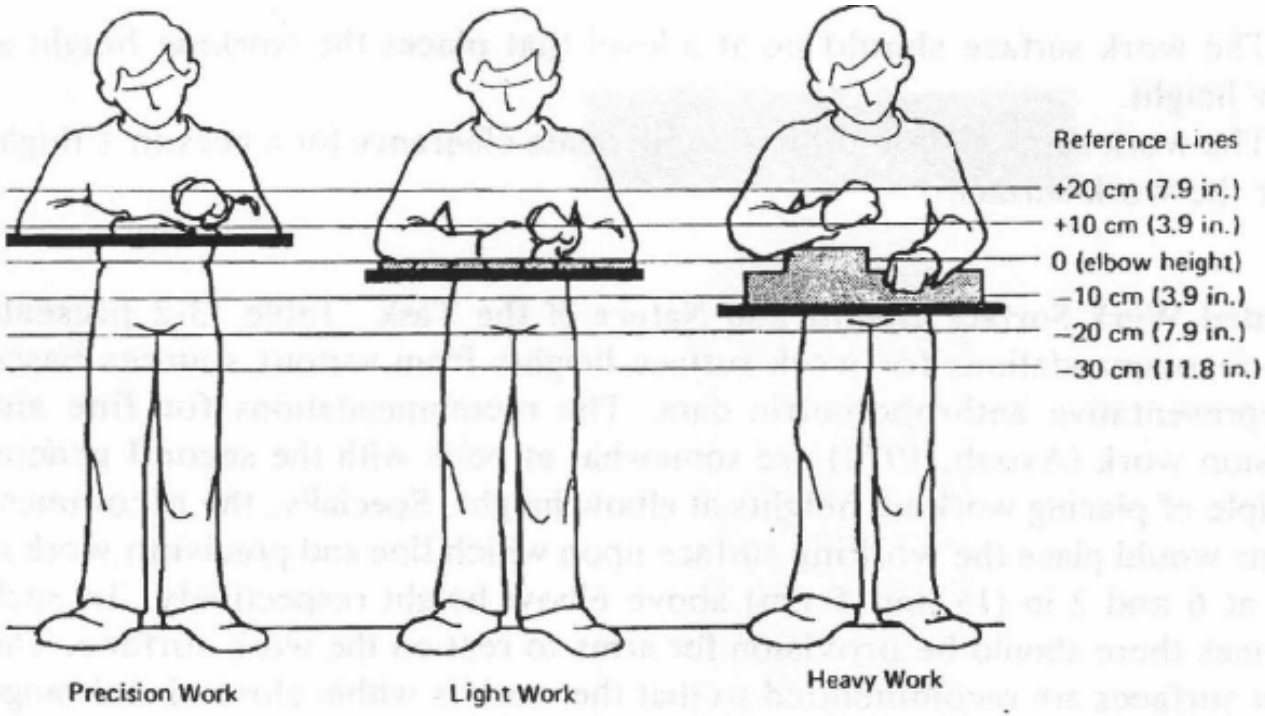
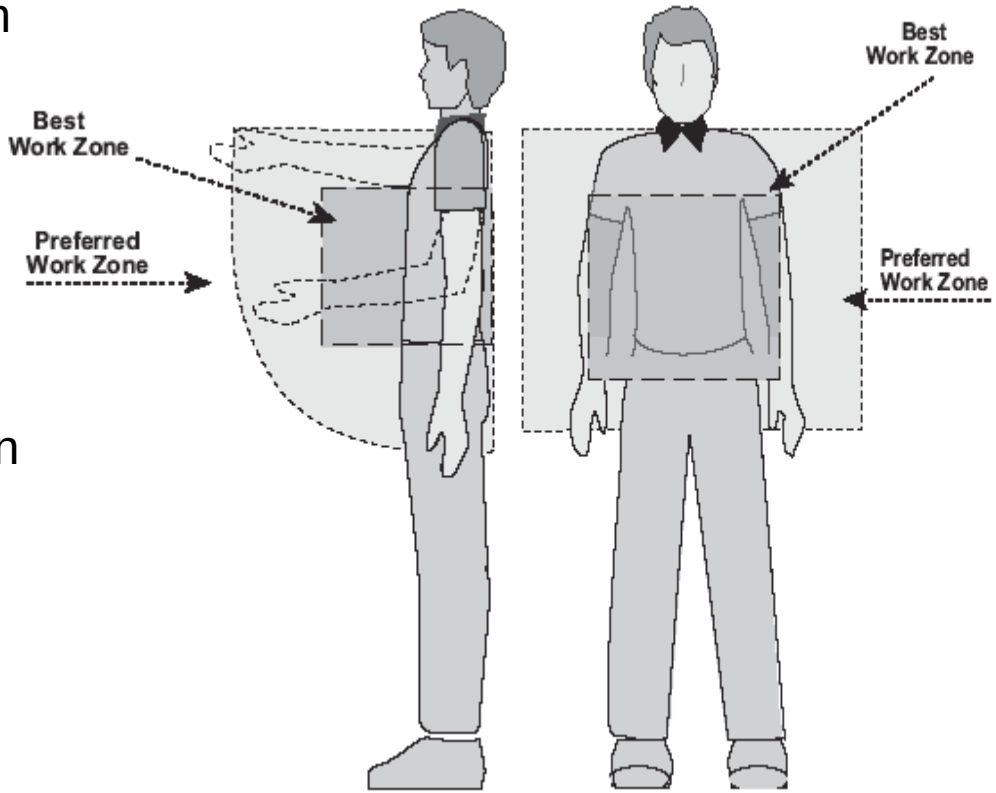


FIGURE 13-13
Relationship between elbow height (from floor) and recommended work-surface height for three types of work performed while standing. The zero horizontal reference line is the elbow height of the individual, and the other lines represent levels above and below. Average elbow height reported by Grandjean for Europeans is 105 cm (41.3 in) for males and 98 cm (38.6 in) for females. (*Adapted from Grandjean, 1988, Fig. 32.*)

Workstation Design

- Optimal Work Zone
  - Best Work Zone
    - As far forward as your wrist when you hold your arm slightly bent
    - As wide as the shoulders
    - Upper level at about heart height
    - Lower level at about waist height
  - Preferred Work Zone
    - As far forward as your hand when you hold your arm out straight
    - A foot on either side of the shoulders
    - Upper level at shoulder height
    - Lower level at tip of fingers with hands held at the side

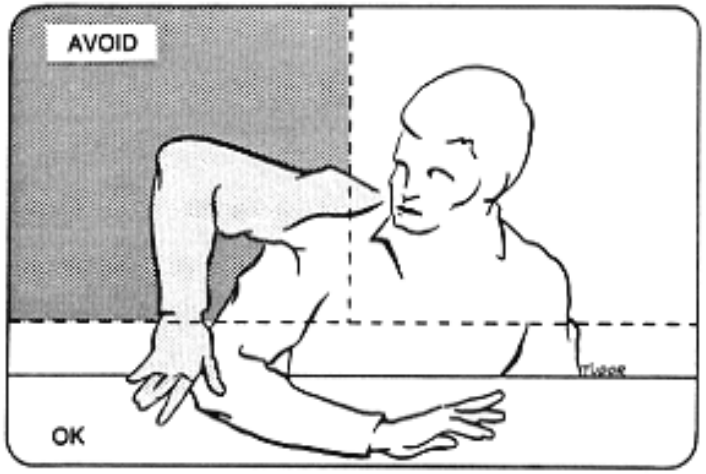


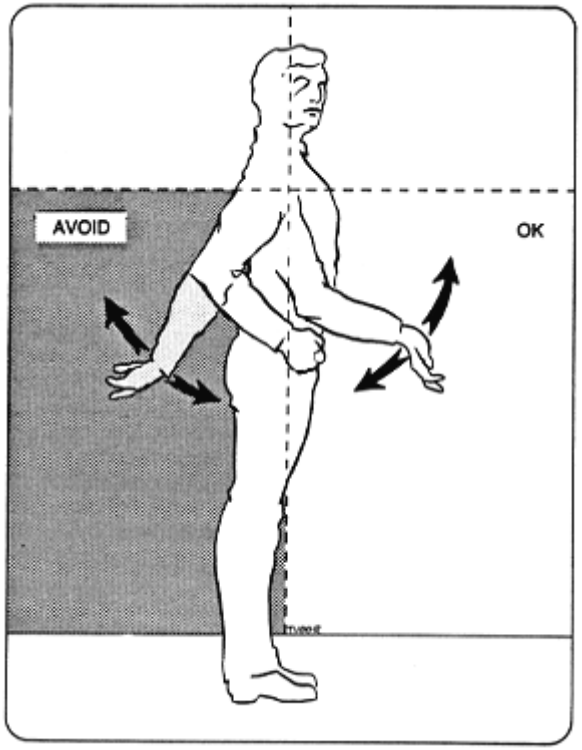
Workstation Design

- Considerations for Workstation Components Layout
  - Clearance requirements
    - Consider the largest users (95th percentile)
  - Reach requirements
    - Consider the smallest users (5th percentile)
  - Adjustability requirements
    - Adjusting the workstation (shape, location, and orientation of the workstation)
    - Adjusting the worker position relative to the workstation (change in seat height, use of platforms or step-up stools)
    - Adjusting the work piece (lift tables, parts bin for easier access)
    - Adjusting the tool (adjustable length tool)

Workstation Design

- Considerations for Workstation Components Layout
  - Work needs to be in front of the employee
    - We need to design tasks in this manner: Reaching behind the body or working with the upper arm raised should be avoided.





Workstation Design

- Considerations for Workstation Components Layout
  - Visibility and Normal Line of Sight
    - Normal line of sight is the preferred direction of gaze when the eyes are at a resting condition.
      - ✓ Most researchers consider it to be about 10-15 degrees below the horizontal plane.
    - Visual displays should be placed within +/- 15 degrees in radius **around** the normal line of sight. This is called the Primary Viewing Area.

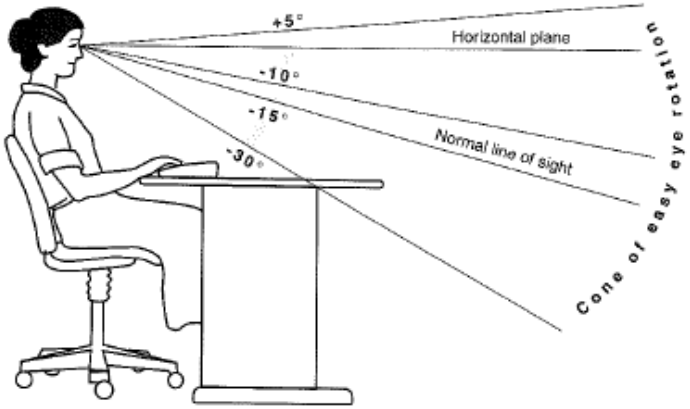


FIGURE 10.6
The normal line of sight and the range of easy eye rotation. (*Source:* Grandjean, E., 1988. *Fitting the Task to the Man* (4th ed.). London: Taylor and Francis. Reprinted by permission of Taylor and Francis.)

Workstation Design

- Considerations for Workstation Components Layout
  - Component arrangement
    - 1) Frequency of use
      - ✓ Frequently used components should be in the primary visual angle.
      - ✓ E.g., Frequently used hand tools near the dominant hand, frequently used foot pedals should be near the dominant foot.
    - 2) Importance principle
      - ✓ Arrange according to priority.
      - ✓ Most crucial in most convenient locations

Workstation Design

- Considerations for Workstation Components Layout
  - Component arrangement
    - 3) Sequence of use principle
      - ✓ Components used in sequence should be located next to each other, in an order reflecting the sequence of operation
      - ✓ Link analysis (total travel time vs sequences)
        - Minimize total travel time (eye or hand movement)

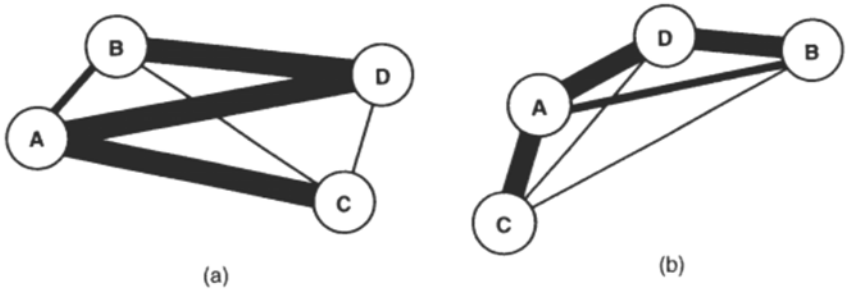


FIGURE 10.10
An example of applying link analysis in system design. Here the width of a link represents the travel times (or the strength of connection) between two components. The purpose of the design in to minimize the total travel time across all components. (a) Before reposition of components. Note that thick lines are long. (b) After reposition. Note that the thick lines are shorter.

Workstation Design

- Considerations for Workstation Components Layout
  - Component arrangement
    - 4) Consistency principle
      - ✓ Components should be laid out in the same spatial locations within the workstation and consistent with other workstations.

Workstation Design

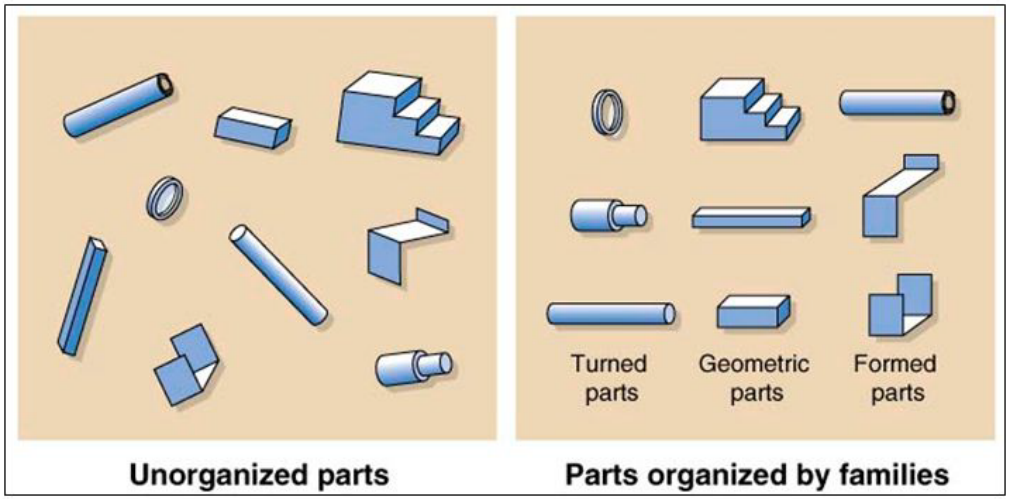
- Considerations for Workstation Components Layout
  - Component arrangement
    - 5) Control – display compatibility
      - ✓ Control devices should be close to their displays.

Workstation Design

- Considerations for Workstation Components Layout
  - Component arrangement
    - 6) Clutter avoidance
      - ✓ Adequate space between adjacent controls to prevent accidental activation

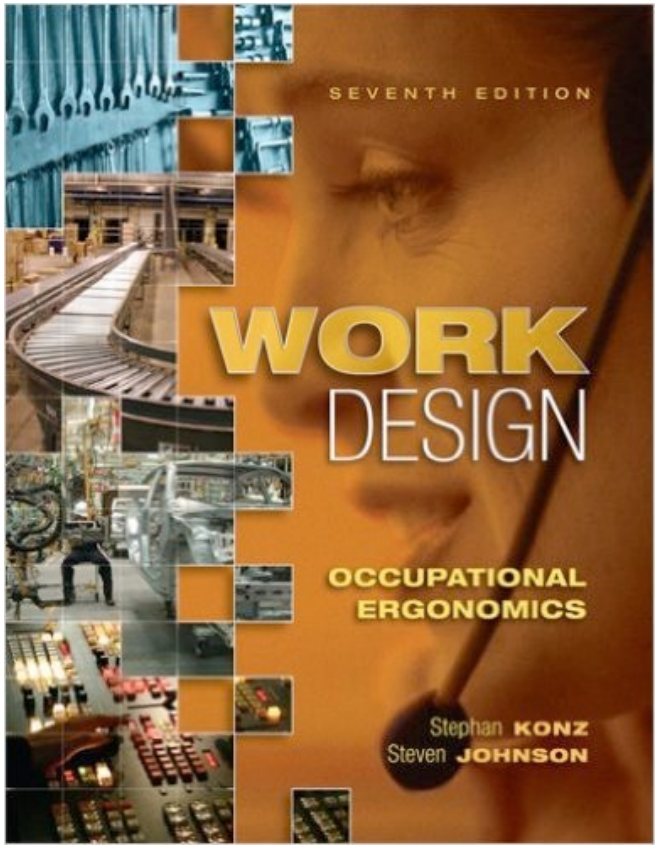
Workstation Design

- Considerations for Workstation Components Layout
  - Component arrangement
    - 7) Functional grouping
      - ✓ Components of closely related functions should be placed close to each other
      - ✓ Various groups should be easily identifiable (colors, shapes, sizes, separation borders)



Workstation Design

- Guidelines
  - What is a guideline?
    - A desirable design feature that is to be incorporated, if possible.
    - A general standard or principle for design.
  - 14 Guidelines
    - Concerning the physical design of the workstation
    - Emphasis: Repetitive work



Konz, S. & Johnson, S. (2008)

Workstation Design

1) Avoid Static Loads and Fixed Work Postures

- Bad for the blood supply of a specific muscle as well as the whole body
- Static loading
  - Standing
  - Falls
    - Slips and falls are the 2nd largest source of unintentional injury deaths!
    - Causes of falls: slips, trips, and stepping-on-air
  - Sitting
  - Head/Neck: Head weight about 6.6kg, a bowling ball
  - Hands/Arms

Workstation Design

2) Reduce Musculoskeletal Disorders

- Work height
- Wrist posture
- Elbow posture
- Reaching behind back
- Hand and arm motions

Workstation Design

3) Set the Work Height at 50 mm Below the Elbow

- Work height: Defined in terms of elbow height.
- Optimum height: Slightly below elbow
- Sitting vs standing: Same optimum height
- Work height and table height: Not the same
- Solutions
  - Change machine height.
  - Adjust elbow height.
  - Adjust work height on machine.
- Considerations
  - Slanted surface
  - Adequate thigh clearance

Workstation Design

4) Furnish Every Employee with an Adjustable Chair

- Cost considerations: The cost of an adjustable chair is very low compared to labor cost.
- Adjustability
- Training
- Chair design
  - ✓ Seats
  - ✓ Backrests
  - ✓ Armrests
  - ✓ Legs/pedestals

Workstation Design

5) Use the Feet as Well as the Hands

- Move more slowly than hands
- More powerful than arms
- Use pedals for power and control, e.g. driving

Workstation Design

6) Use Gravity; Don’t Oppose It

- Movement direction: Make movements horizontal or downward; avoid lifting.
- Consider using the weight of the body to increase mechanical force.
- Use gravity as a fixture
- Use gravity in feeding and disposal

Workstation Design

7) Conserve Momentum

- Avoid unnecessary acceleration (increase in speed) and deceleration (decrease in speed) since they take both time and energy
  - Use circular motion for stirring and polishing
  - Eliminate grasping motions by providing lips, rolled edges, and holes
  - Avoid transporting weight in the hand

Workstation Design

8) Use 2-Hand Motions Rather Than 1-Hand Motions

- Cranking with 2 arms is 25% more efficient than with one.
- Two-hand actions: More productive
- Hand as fixture: Don’t use the hand as a fixture.

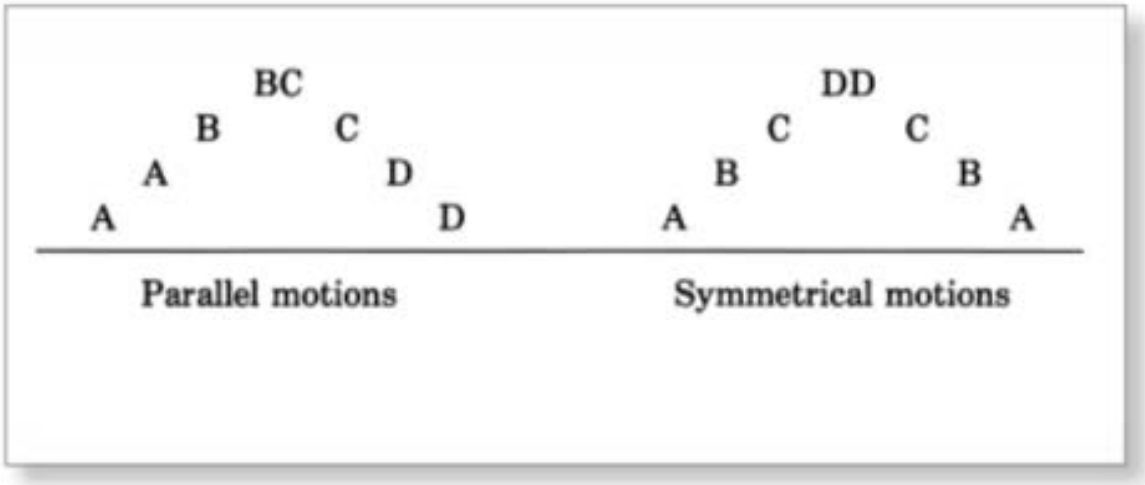
Workstation Design

9) Use Parallel Motions for Eye Control of 2-Hand Motions

- Spread vs symmetry
  - Cost of eye control
    - Predetermined time systems
      - ✓ Time cost
        - Eye focus
        - Eye travel

FIGURE 11.25

Parallel vs. symmetrical motions. When is each best?



Workstation Design

10) Use Rowing Motions for 2-Hand Motions

- Rowing motions are more efficient and provide greater power

Workstation Design

11) Pivot Motions About the Elbow

- E.g. movement of only the forearm
- Motion time: Pivot motion about the elbow < pivot motion about the shoulder (movement of both the forearm and upper arm)
- Accuracy: Cross-body movements (pivot only on the shoulder) > pivot motion about the elbow
  - Should be avoided, since it costs more energy to move the whole arm.
- Physiological cost is lower for movements about the elbow

Workstation Design

12) Use the Preferred Hand

- The dominant hand is
  - 10% faster for reach-type motions
  - More accurate than the non-dominant
  - More exposed to cumulative trauma
  - 5% to 10% stronger

Notes: Work should arrive from the operator's preferred side and leave from the non-preferred side.

Workstation Design

13) Keep Arm Motions in the Normal Work Area

- Work benches: Avoid long benches
- Material handling equipment
- High use: Keep it close
- Shoulder sensitivity: The shoulder is very sensitive to small changes in workplace layout.

Workstation Design

14) Let the Small Person Reach; Let the Large Person Fit

- Designing for most of the population
- Both sexes
- Multiperson use
- Civilian ≠ military
- International populations
- Excluded proportion