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Introduction to Ergonomics and Industrial Safety

Section Three

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2012 E.C

- ***Anthropometry*** can be defined as the study of physical dimensions of human body. Anthropometric measures provide information about various dimensions of human body such as height and how these values are distributed within the population.

- The goal of using anthropometric data to design workspaces, machinery and clothing is to match the physical dimensions of the devices to the physical dimensions of human body.
- Examples are clothing, workspace, (work) environment, tools, equipment, machines.

- Examples are clothing, workspace, (work) environment, tools, equipment, machines.
- If factors such as height and reach are not considered, the work activity can lead to bad postures which can result in pain and work-related injuries

Six Pillars of Ergonomic Design

1. ***User Orientation:*** Design and application of tools, procedures, and systems must be user oriented, rather than just "task" oriented
2. ***Diversity:*** Recognition of diversity in human capabilities and limitations, rather than "stereotyping" workers/users
3. ***Effect on Humans:*** Tools, procedures, and systems are not "inert", but do influence human behaviour and well-being

4. ***Objective Data:*** Empirical information and evaluation is key in design process, rather than just use of "common sense"
5. ***Scientific Method:*** test and retest hypothesis with real data, rather than "anecdotal" evidence or "good estimates"
6. ***Systems:*** object, procedures, environments, and people are interconnected, affect one another, and do not exist in "isolation"

General Principles of Reaches and Clearances for Job

- It is important to have both adequate workspace and easy access to everything that is needed, with no barriers in the way
- Lack of clearance can create bumping hazards or force
  you to work in contorted postures.
- It can increase long reaches, especially if there is inadequate space for knees or feet.

1. Design for tall people

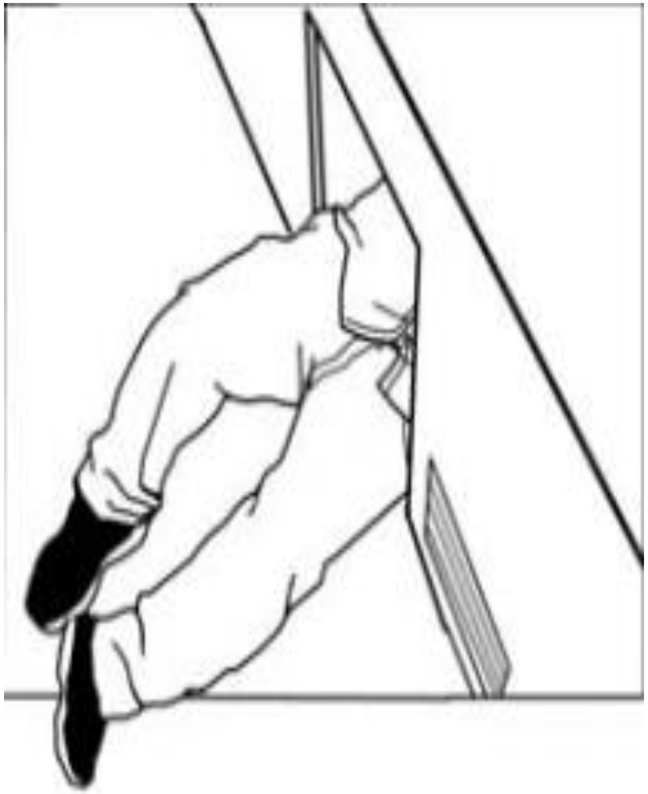
- In general, the goal is to make sure that tall people have enough clearance, that is, room fo the head, knees, elbows, and feet.
- If tall people can fit, then so can everyone else.

To improve access:

- ✓ Reorganize equipment, shelves, etc.
- ✓ Increase the size of openings
- ✓ Eliminate obstructions between the person and the items needed to accomplish the task

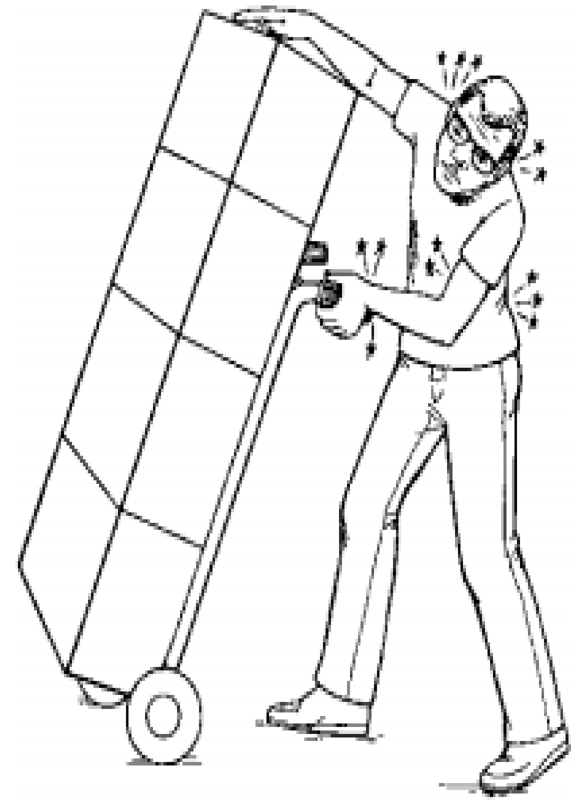
2.Maintainability

- Probably the single biggest problem that maintenance personnel encounter in their tasks is lack of clearance.
- Many activities would be easy to perform, if you could only reach an item and work on it with easy access
- The remedy is designing with easy access in mind — quick disconnects, removable panels, improved configuration, and relocation of frequently accessed equipment.



Provide visual access

- A similar issue is visual access.
- Visual access is the ability to see what yo are doing or to see dials and displays.
- A common issue is inability to see when moving a cart or lift truck.
- Equally common are machines where various gauges are distant from the operator's position.
- General workstations can improved by removing barriers and changing layouts to provide better line of sight

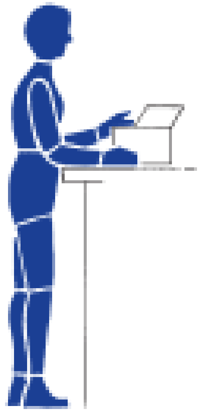
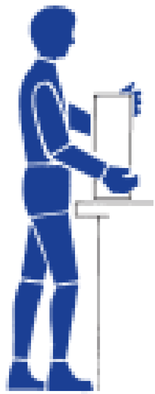


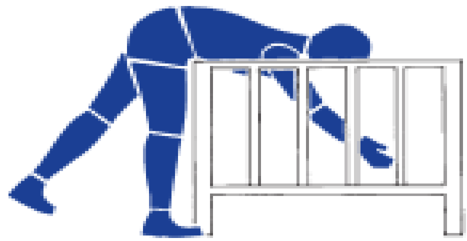
Ergonomic Principles that Contribute to Good Workplace Design

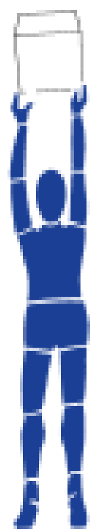
- The goal for the design of workplaces is to design for as many people as possible and to have an understanding of the Ergonomic principles of posture and movement which play a central role in the provision of a safe, healthy and comfortable work environment
- Posture and movement at work will be dictated by the task and the workplace, the body's muscles, ligaments and joints are involved in adopting posture, carrying out a movement and applying a force

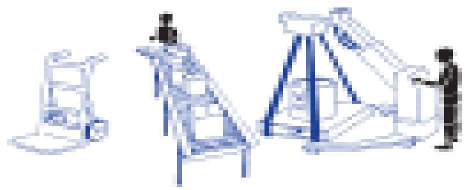
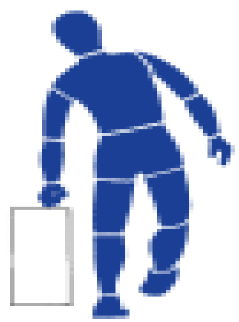
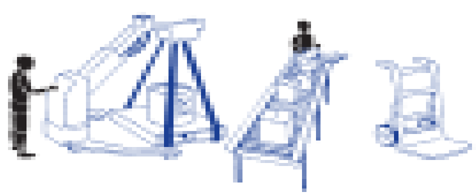
Con…

- The muscles provide the force necessary to adopt a posture or make a movement.
- Poor posture and movement can contribute to local mechanical stress on the muscles, ligaments and joints, resulting in complaints of the neck, back, shoulder, wrist and other parts of the musculoskeletal system.
- Ergonomic principles provide possibilities for optimizing tasks in the workplace
- These principles are summarized in table

Ergonomic Principle		Description
Joints must be in a neutral position		In the neutral position the muscles and ligaments, which span the joints, are stretched to the least possible extent
Keep work close to the body		If the work is too far from the body, the arms will be outstretched and the trunk bent over forwards

Avoid bending forward		The upper part of the body of an adult weighs about 40kg on average. The further the trunk is bent forwards, the harder it is for the muscles and ligaments of the back to maintain the upper body in balance
A twisted trunk strains the back		Twisted postures of the trunk cause undesirable stress to the spine
Alternate posture as well as movements		No posture or movement should be maintained for a long period of time. Prolonged postures and repetitive movements are tiring.

Avoid excessive reaches		It is necessary to limit the extent of forward and sideways reaches to avoid having to bend over or twist the trunk
Avoid carrying out tasks above shoulder level		The hands and elbows should be well below shoulder level when carrying out a task

Limit the weight of a load that is lifted		There are guidance weight limits for both males and females detailed in Figure 2 of this document
Use mechanical aids		Many lifting accessories are available to help lift and move loads
Avoid carrying loads with one hand		When only one hand is used to carry a load, the body is subject to mechanical stress
Use transport accessories		There are a large number of accessories such as roller conveyors, conveyor belts, trolleys and mobile raising platforms, which eliminate or reduce manual handling.

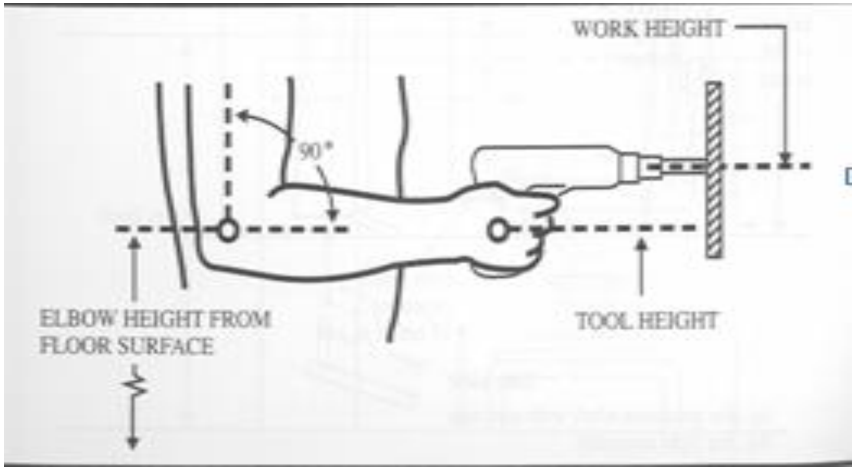
General Principle Of Workplace Designs :

- Workstation designs incorporate accommodation of employees who actually perform job requirements

1. **Determine Work Surface Height by Elbow Height** (seated or standing)

✓ Upper arms are hanging down naturally and elbows are flexed at 90 deg

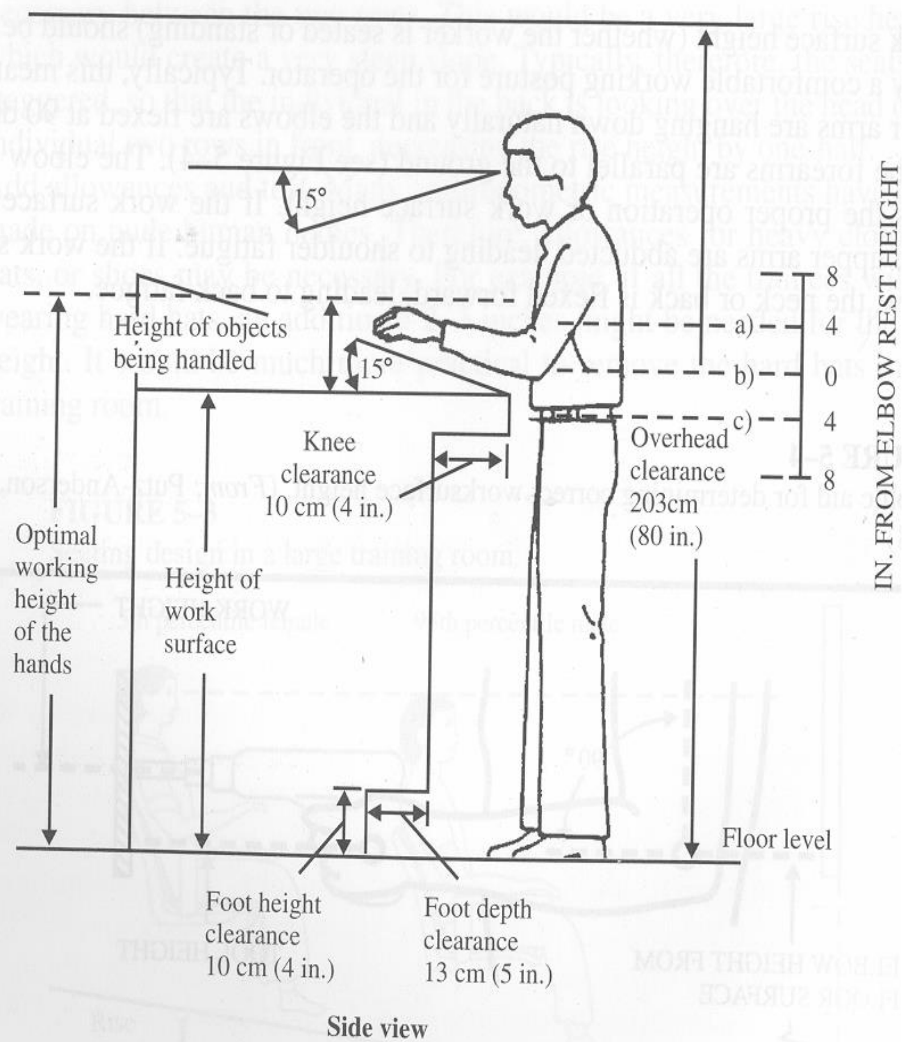
✓ If work surface is too high /low, upper arms are abducted, or back is flexed forward, leading to shoulder/ back fatigue.



2.Adjust the Work Surface Height Based on the Task Being Performed

- For rough heavy work, lower the surface (20 cm), for stronger trunk muscles. For fine assembly, raise the surface (20 cm), to bring the details closer to the eye.
- Slanting the work surface approx.15 deg can satisfy both principles

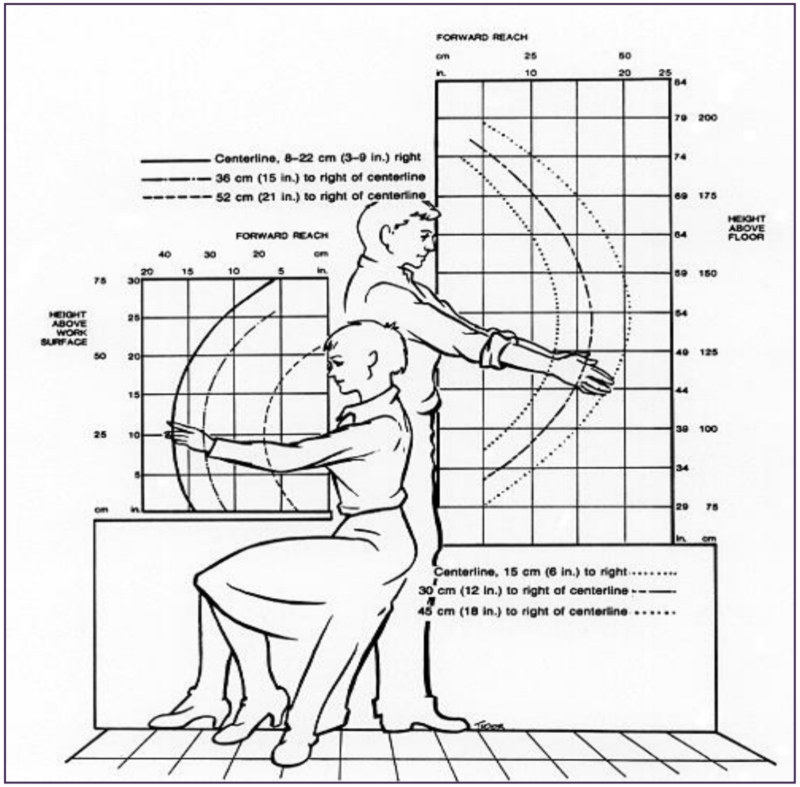
FIGURE 5–5
Recommended standing workplace dimensions.



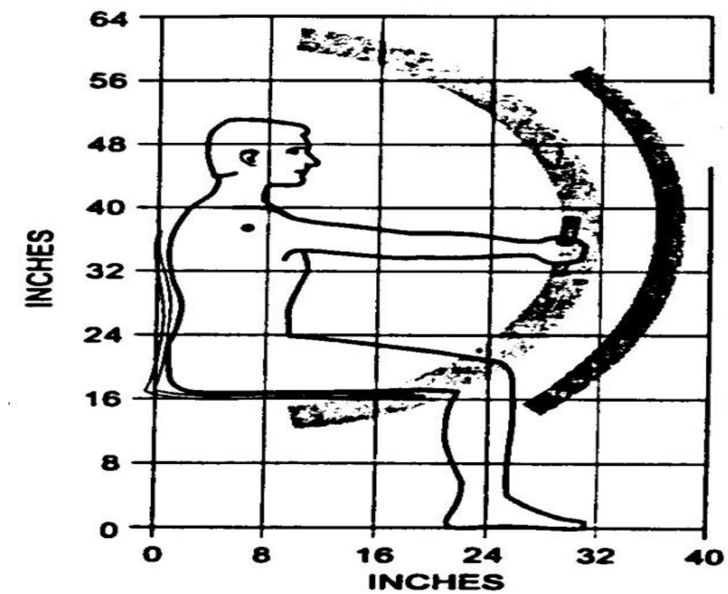
(a) For precision work with arm rest
(b) For light assembly
(c) For heavy work

Reach/Work Envelopes

- These pictures show reaches for employees. The first picture shows the overhead shot of a worker at a work station. It defines acceptable reaches and work zones for people.



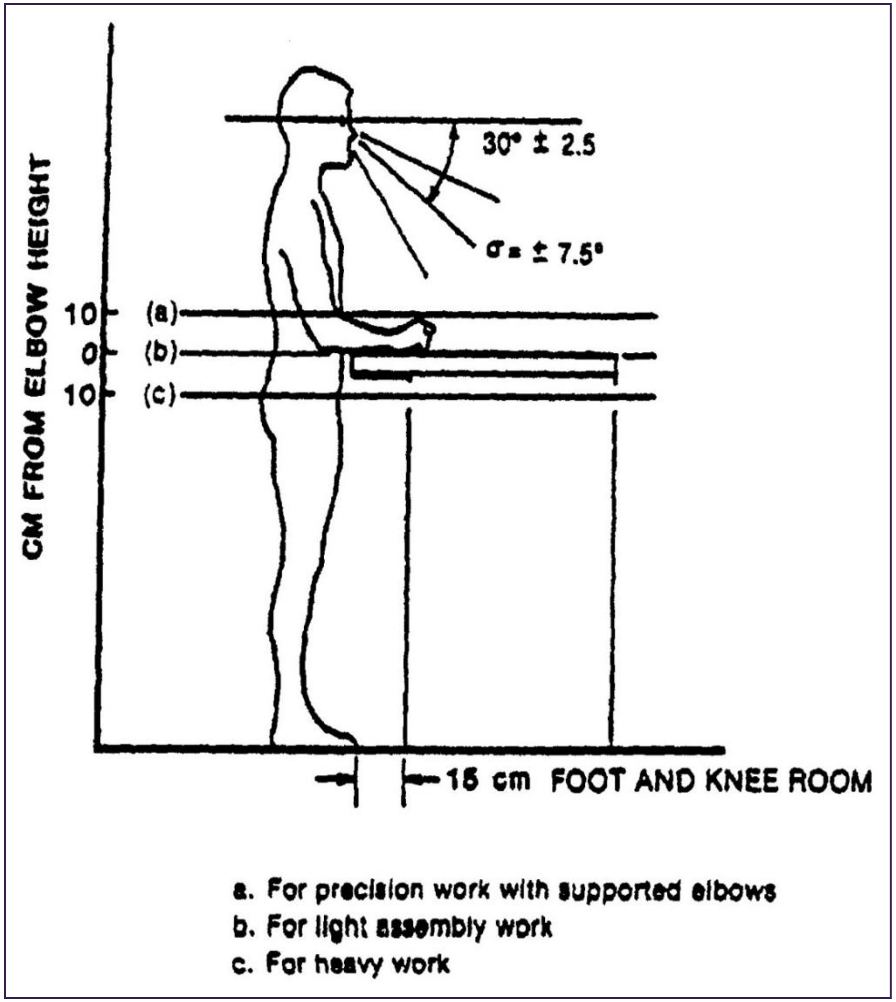
- shows the side view for a seated person. It shows the acceptable reaches for a person who has to grasp an object. You will notice that both pictures express the reaches in arcs.

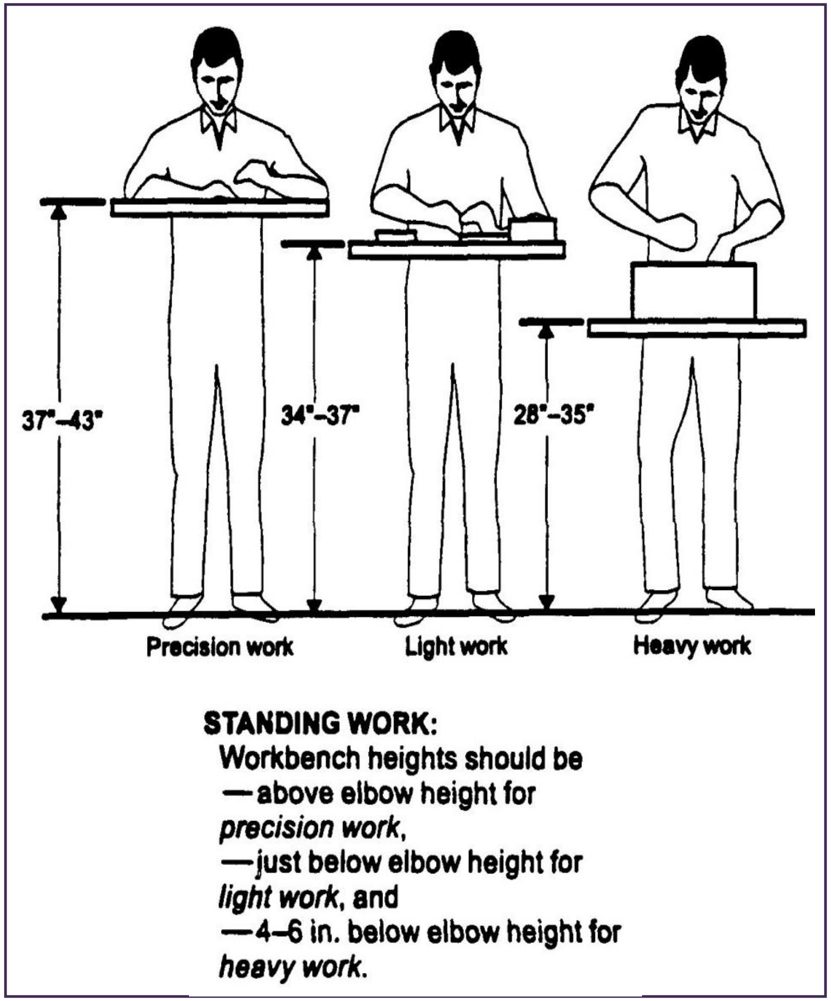


SEATED WORK:
Boundaries for vertical reaches for grasping objects.

Con…

Work Surface Heights





3. Provide a Comfortable Chair for the Seated Operator

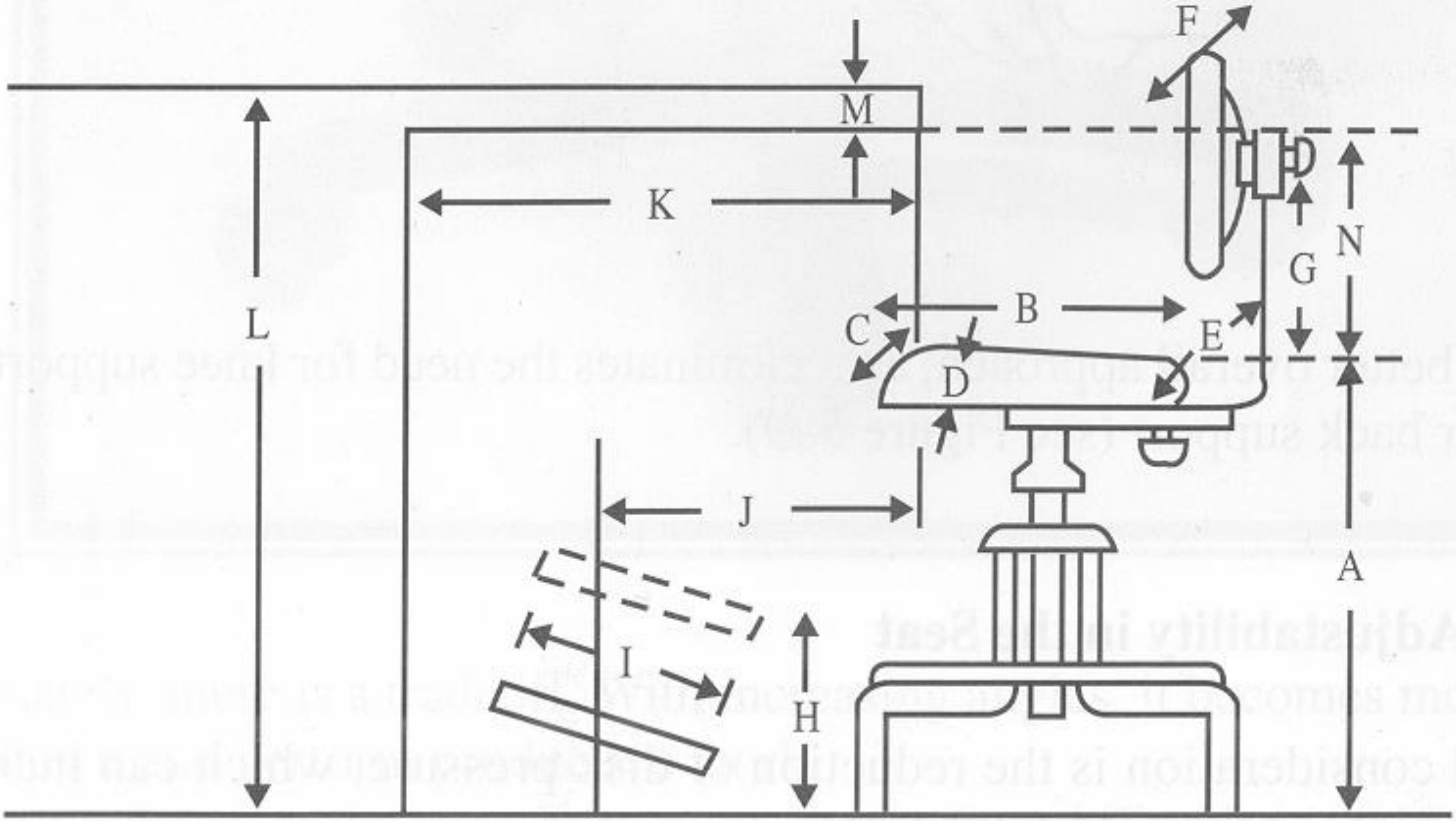
- The seated posture is important for reducing both stress on the feet and energy expenditure.
- When standing erect, the lumbar portion of the spine (the back at belt level) curves inward, and rotates backward, flattening the curve and increasing the pressure on the disks.
- Therefore, provide *lumbar support* in the form of an outward bulge in the seat back.
- Reduce the pelvic rotation by maintaining a large angle between the torso and thighs, via a forward-tilting seat (kneeling posture).

4. Provide Adjustability in the Seat

- Provide adjustability for specific seat parameters (height)
  - too high seat compress underside of thighs. too low will raise the knees uncomfortably high and decrease trunk angle.
- Arm-rests for shoulder and arm support and foot-rests for shorter individuals are recommended.
- Casters assist in movement and ingress/egress from workstations.
- Chair should be slightly contoured, slightly cushioned, and covered in a fabric to prevent moisture buildup.

FIGURE 5–6

Adjustable Chair. (Specific seat parameter values found in Table 5–2)



Properly adjusted workstation.

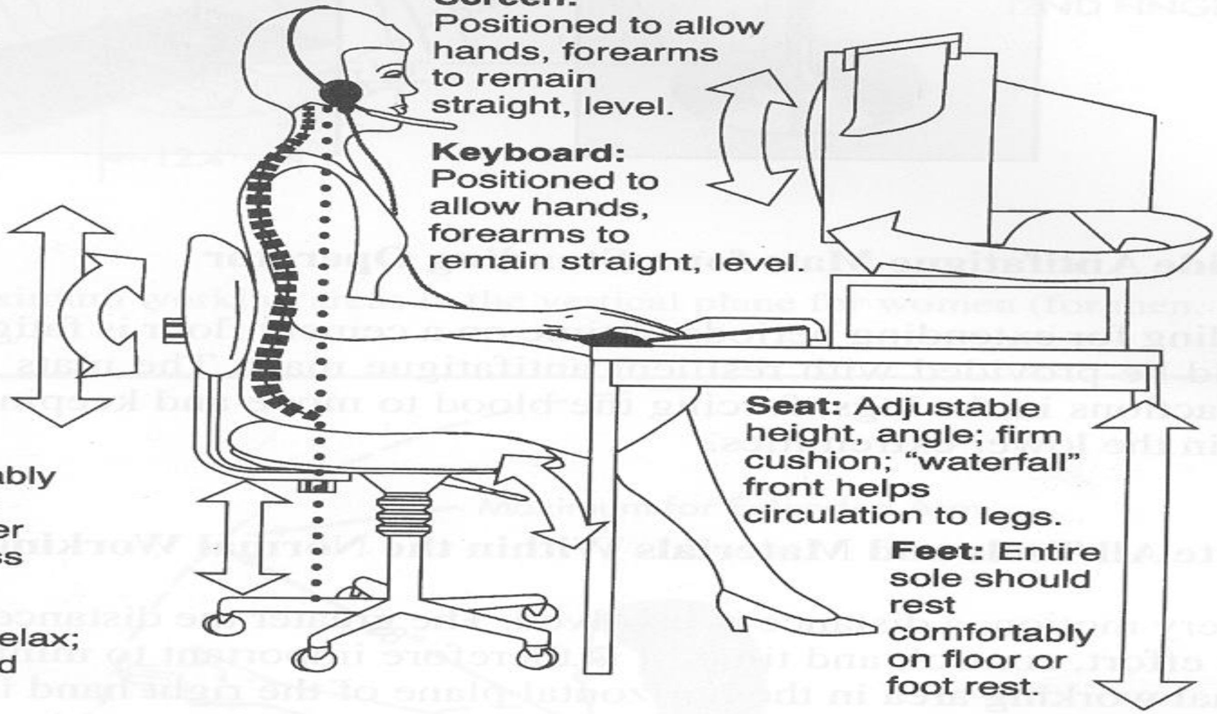
Arms: When operator's hands are on keyboard, upper arm and forearm should form right angle; hands should be lined up with forearm; if hands are angled up from the wrist, try using attached to front of keyboard; optional arm rests should be adjustable.

Telephone: Cradling telephone receiver between head and shoulder can cause muscle strain; headset allows head, neck to remain straight while keeping hands free.

Document holder: Same height and distance from user as the screen, so eyes can remain focused as they look from one to the other.

Screen: Positioned to allow hands, forearms to remain straight, level.

Keyboard: Positioned to allow hands, forearms to remain straight, level.



Backrest: Adjustable for occasional variations; shape should match contour of lower back, providing even pressure and support.

Posture: Sit all the way back into chair for proper back support; back, neck should be as comfortably straight ahead; knees should be slightly lower than hips; do not cross legs or shift weight to one side; give joints, muscles a chance to relax; periodically, get up and walk around.

Seat: Adjustable height, angle; firm cushion; "waterfall" front helps circulation to legs.

Feet: Entire sole should rest comfortably on floor or foot rest.

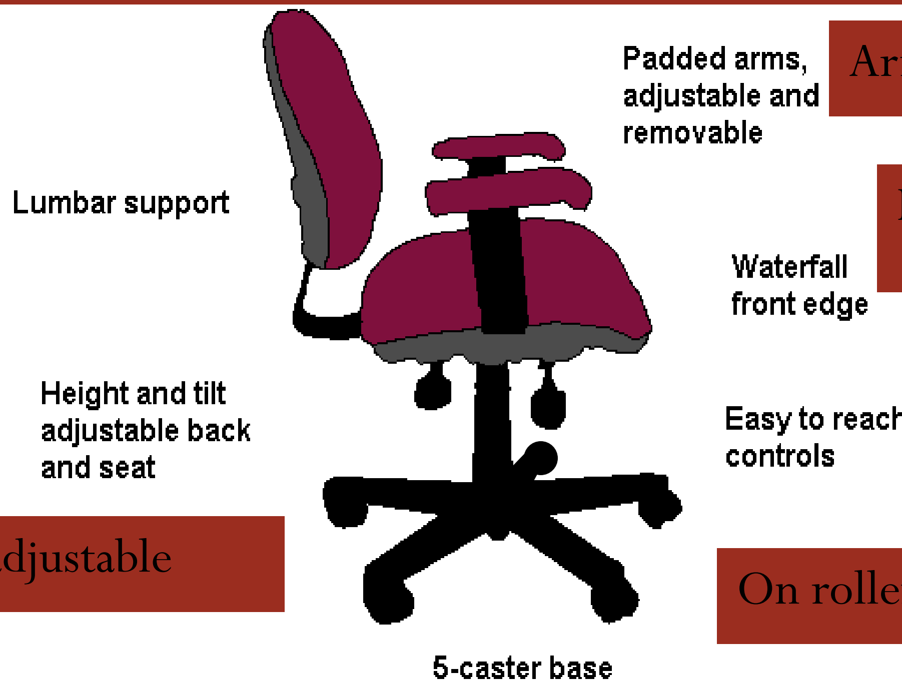
Desk: Thin work surface to allow leg room and posture adjustments; adjustable surface height preferable; table should be large enough for books, files, telephone while permitting different positions of screen, keyboard, mouse pad.

Avoiding eye strain:

1. Getting glasses that improve focus on screen; measure distance before visiting eye doctor.
2. Try to position screen or lamps so that lighting is indirect; do not have light shining directly at screen or into eyes.
3. Use a glare-reducing screen.
4. Periodically rest eyes by looking into the distance.

Office Ergonomics- The right equipment, right place
Use a good CHAIR

Backrest is provides good lower back support



Arms adjustable

Front edge of seat pan curves down

Seat pan adjustable horizontally and tilts

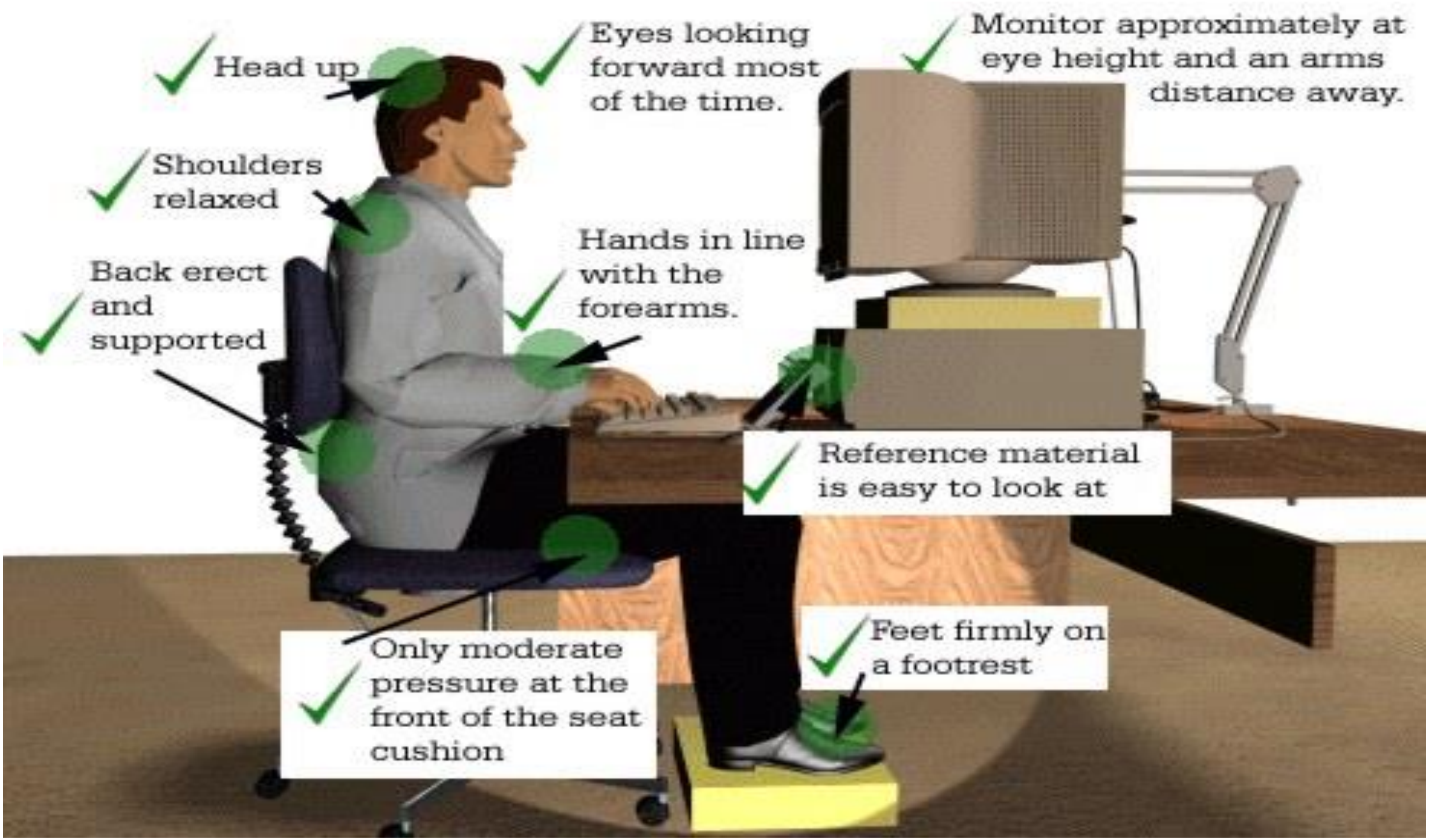
Height adjustable

On rollers

Five feet for base-most stable

Bad office working Condition

Ideal Office



Encourage Postural Flexibility

- The work station height should be adjustable so that the work can be performed efficiently either standing or sitting. The human body is not designed for long periods of sitting. The disks blood supply rely on pressure changes to receive nutrients. Postural rigidity also reduces blood flow to the muscles and induces muscle fatigue and cramping.
- Provide a sit/stand stool so that the operator can change postures easily. Two key features: height adjustability, and a large base of support, preferably long enough that the feet can rest on and counterbalance

Goals of Workplace Design and Layout

- Maximize performance and minimize hazards:
- 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. 30% time increase when working overhead)
- Provide force capability
  - strength data and models

Principles of Work System Design

- **Consider the WHOLE work system,**
- ✓ Formulate goals
- ✓ Analyze and allocate functions
- ✓ Draw up design concept
- ✓ Determine detailed design
- ✓ Implement and validate
- ✓ Evaluate

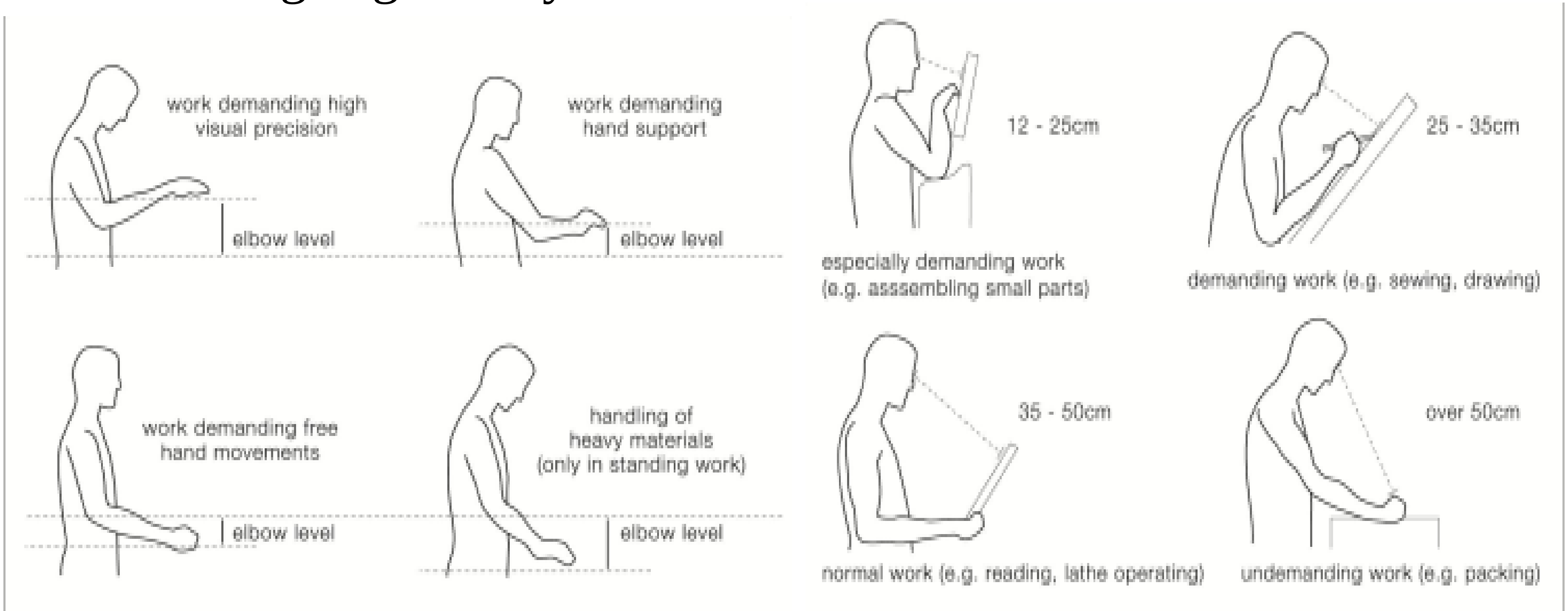
NB: design process is iterative and consultative (ISO 6385)

Layout of Workspaces

- **Workspace size**
  - ✓ Suitable for functions to be performed (incl. maintenance tasks)
  - ✓ Lighting, tempt appropriate for functions to be performed
  - ✓ Review needs with changing/evolving functions and equipment
- **Workspace arrangements**
  - ✓ Facilitates appropriate work postures
  - ✓ Adequate space for all equipment

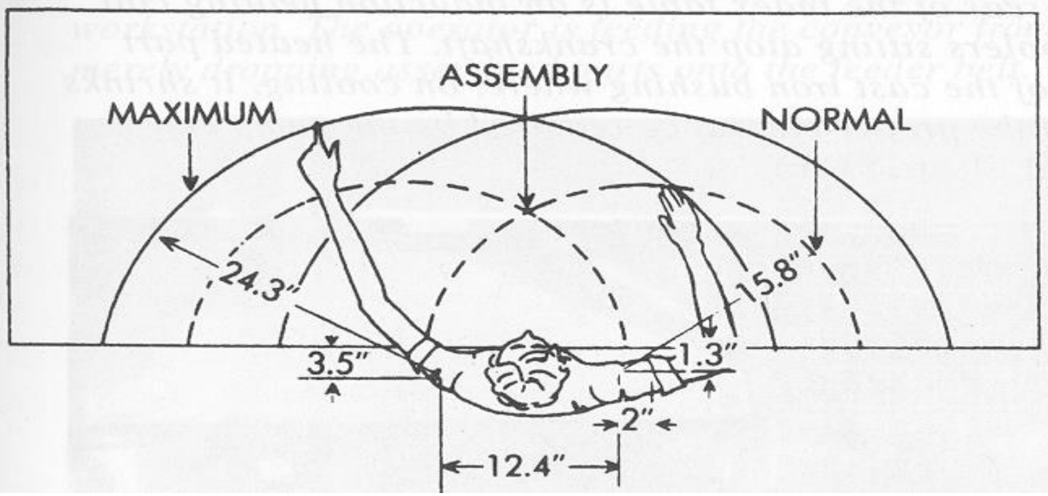
Workstation Design

- Viewing distances proportional to size of work object
  – Small object, shorter viewing distance, higher work surface
- Ensure viewing distances cater for all ages
- Viewing angles vary from 15o-45o

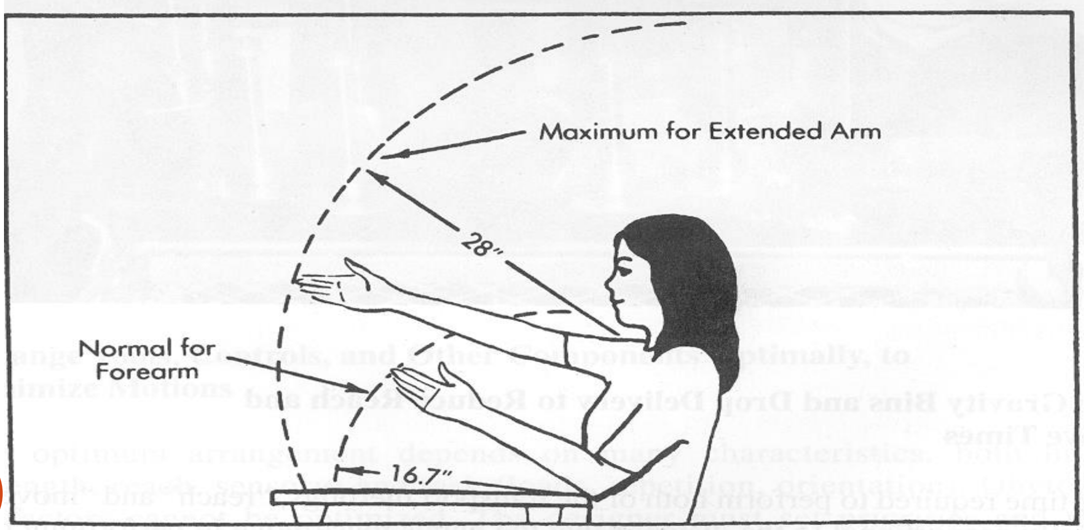


Con…

Normal and maximum working areas in the horizontal plane fc
by 1.09).



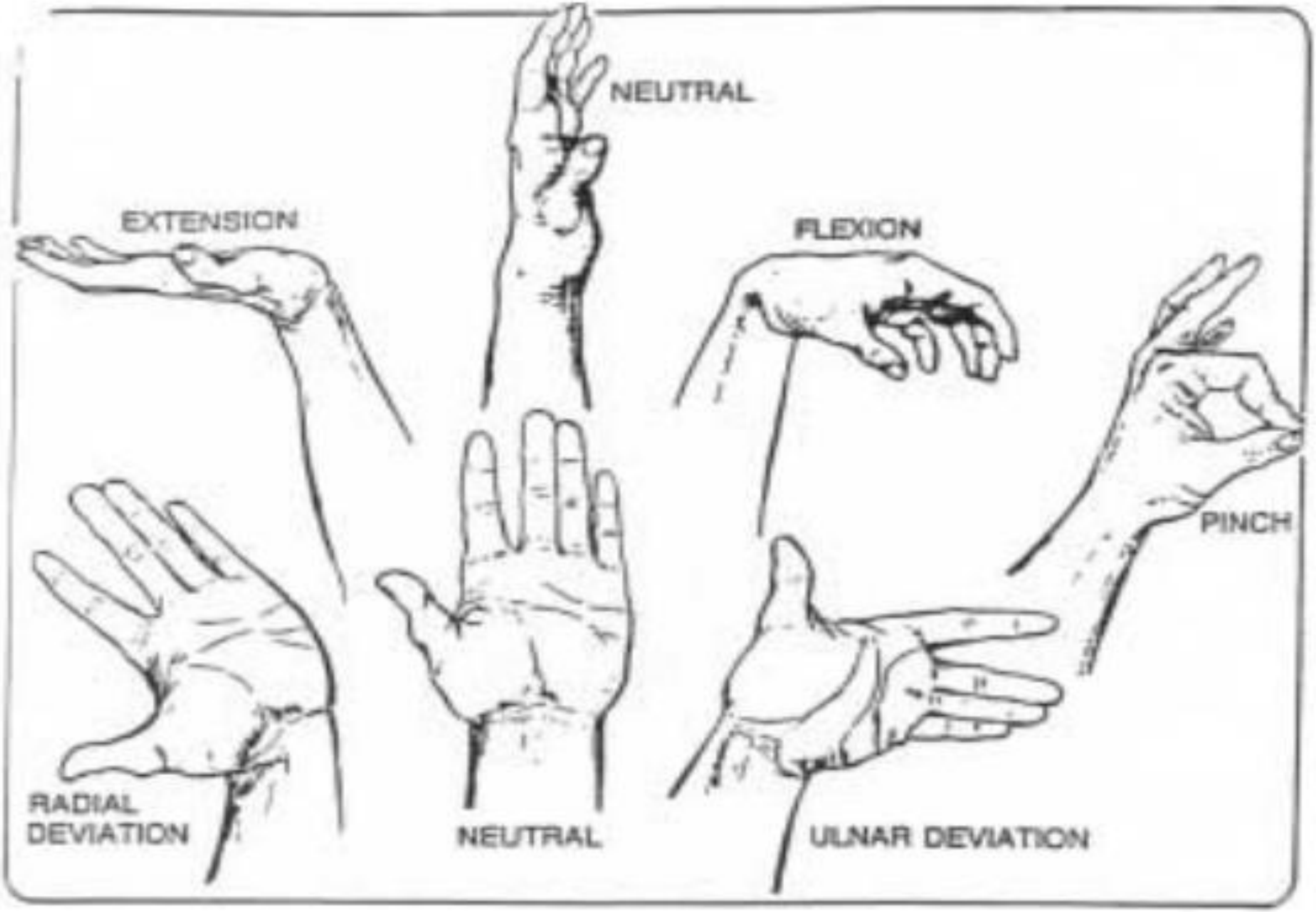
Normal and maximum working areas in the vertical plane for women (for men, multiply by 1.09).



The worker eventually learns the fixed locations without wasting time looking and searching.

work place postures and motions in design

- Posture and movement play a central role in ergonomics
- At work and in everyday life, postures and movements are often imposed by the task and the workplace
- The body's muscles, ligaments and joints are involved in adopting a posture, carrying out a movement and applying a force
- Poor posture and movement can lead to local mechanical stress on the muscles, ligaments and joints, resulting in complaints of the neck, back, shoulder, wrist and other parts of the musculoskeletal system


NEUTRAL
EXTENSION
FLEXION
PINCH
RADIAL
DEVIATION
NEUTRAL
ULNAR DEVIATION

work place postures and motions in design

- Ultimately, the workplace should be comfortable for users and adapt to their needs as much as possible
- The human body has a natural range of motion (ROM). Movement within the proper ROM promotes blood circulation and flexibility which could lead to more comfort and higher productivity
- By considering both ROM and repetitive motion, products can be designed to operate within the optimal ranges to help reduce the occurrence of fatigue and muscle disorders

Con…

- Good and Bad Zones

✓ There are 4 different zones that a user might encounter while sitting or standing:

1. Zone 0 (Green Zone) Preferred zone for most movements.

   Puts minimal stress on muscles and joints.

2. Zone 1 (Yellow Zone) Preferred zone for most movements.

   Puts minimal stress on muscles and joints

3. Zone 2 (Red Zone) More extreme position for limbs, puts

   greater strain on muscles and joints

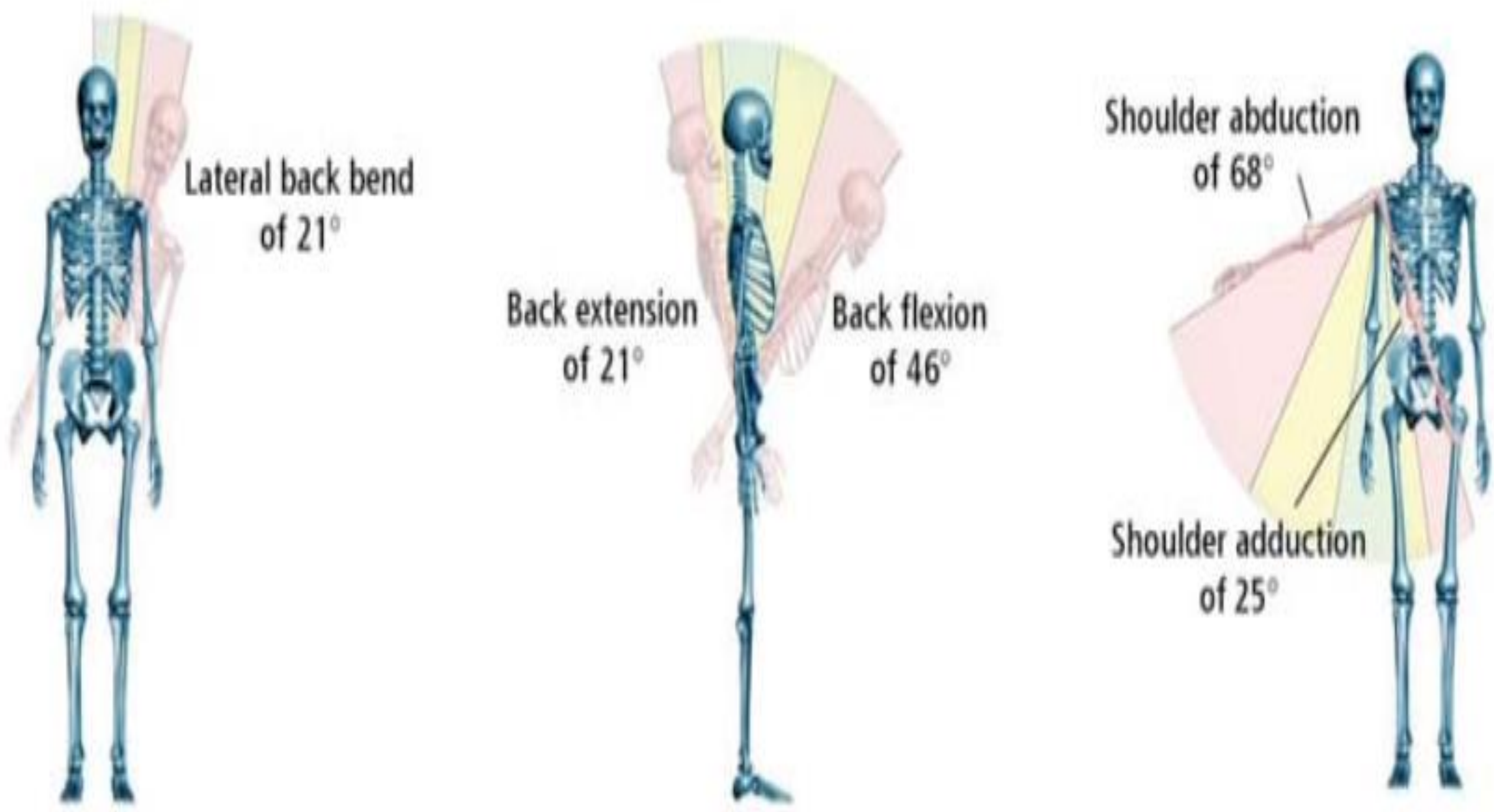
Con….

- Zone 3 (Beyond Red Zone) Most extreme positions for limbs, should be avoided if possible, especially with heavy lifting or repetitive tasks
- Zones 0 and 1 include smaller joint movements, while Zones 2 and 3 represent more extreme positions.
- Zone 0 and Zone 1 are preferred for most movements to occur.

Con…

- Zones 2 and 3 should be avoided when possible, especially for repetitive and heavy tasks.
- Motion in these ranges puts more strain on muscles and tendons and could lead to the development of musculoskeletal disorders.
- Zone 0 is in green, Zone 1 is in yellow, and Zone 2 is in red. Zone 3 is anywhere beyond the red.

Various ranges of motion for different joints



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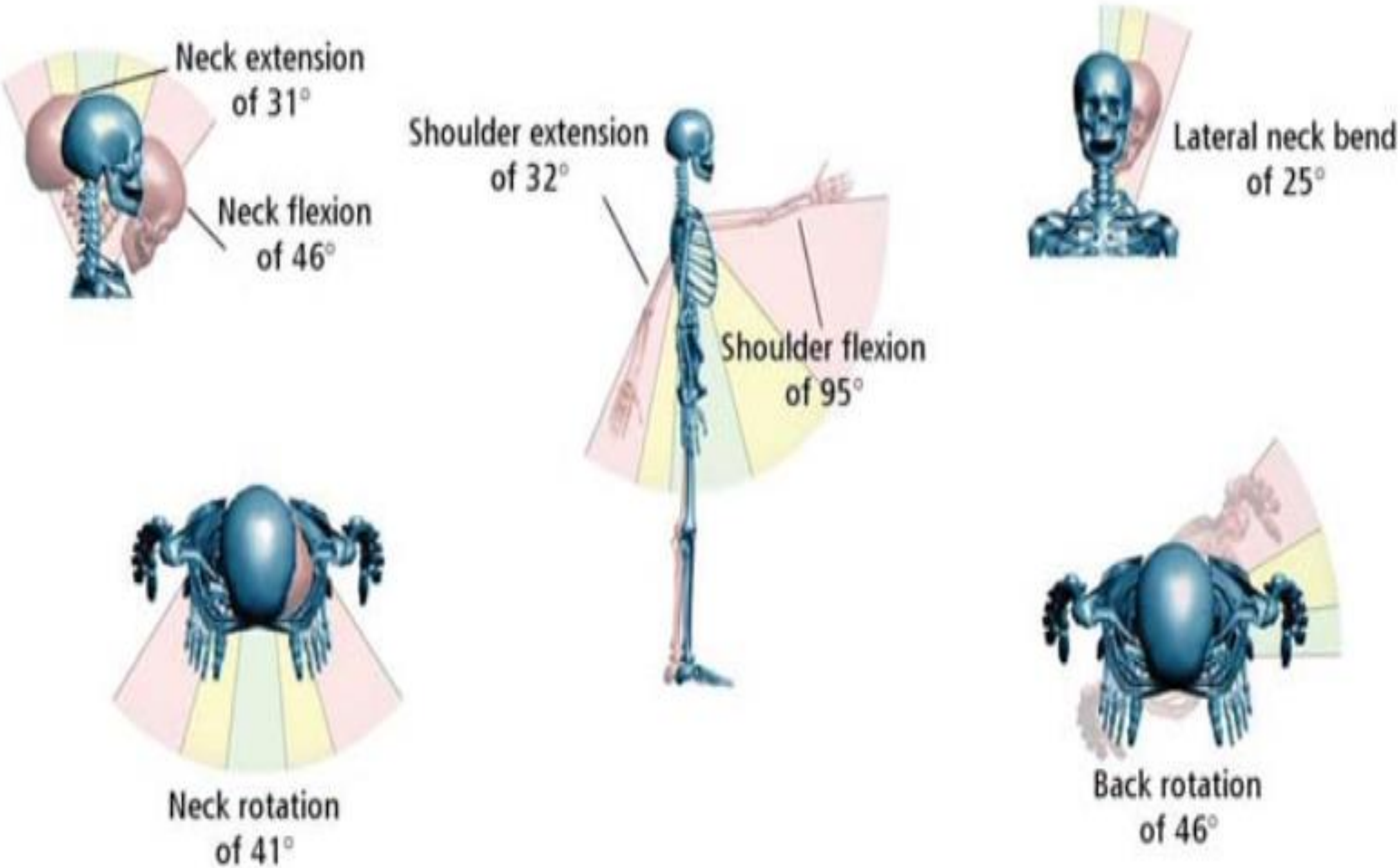
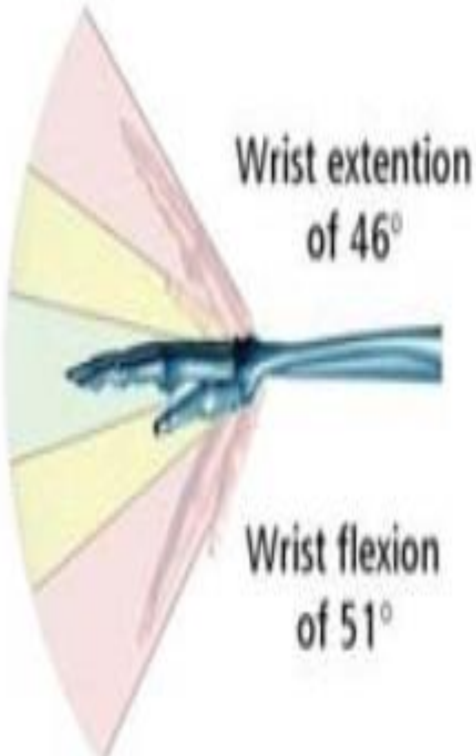
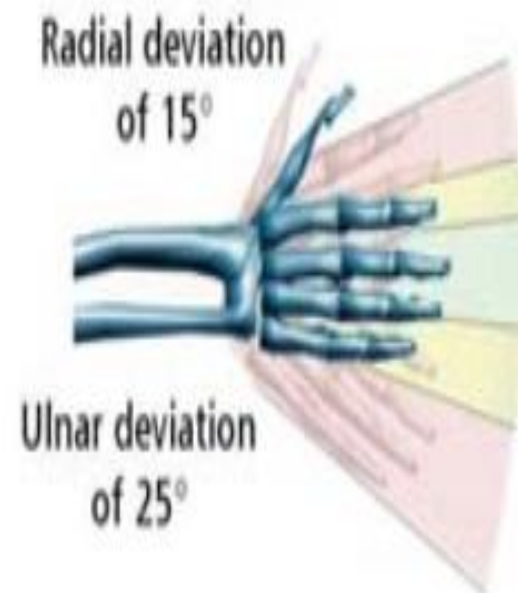


Neck extension
of 31°
Neck flexion
of 46°
Shoulder extension
of 32°
Shoulder flexion
of 95°
Lateral neck bend
of 25°
Neck rotation
of 41°
Back rotation
of 46°

Con…



Zone	
Green	0
Yellow	1
Red	2
Beyond Red	3



Range of Motion

	Movement	Range of Motion Zones 0	1	2	3
Wrist	Flexion	0 – 10	11 – 25	26 – 50	51+
	Extension	0 – 9	10 – 23	24 – 45	46+
	Radial Deviation	0 – 3	4 – 7	8 – 14	15+
	Ulnar Deviation	0 – 5	6 – 12	13 – 24	25+
Shoulder	Flexion	0 – 19	20 – 47	48 – 94	95+
	Extension	0 – 6	7 – 15	16 – 31	32+
	Adduction	0 – 5	6 – 12	13 – 24	25+
	Abduction	0 – 13	14 – 34	35 – 67	68+
Back	Flexion	0 – 10	11 – 25	26 – 45	46+
	Extension	0 – 5	6 – 10	11 – 20	21+
	Rotational	0 – 10	11 – 25	26 – 45	46+
	Lateral Bend	0 – 5	6 – 10	11 – 20	21+
Neck	Flexion	0 – 9	10 – 22	23 – 45	46+
	Extension	0 – 6	7 – 15	16 – 30	31+
	Rotational	0 – 8	9 – 20	21 – 40	41+
	Lateral Bend	0 – 5	6 – 12	13 – 24	25+

Design of Tooling and Equipment

1. Work-holding devices should be designed for the task

- A mechanical work holder with a fast-acting clamp and custom-designed permits the work unit to be loaded quickly and frees both hands to work on the task productively.

2. Hands should be relieved of work elements that can be performed by the feet using foot pedals

- Sewing machines are examples in which foot pedals are used as integral components in the operation of the equipment.

Con…

3. Combine multiple functions into one tool where possible

- Many hand tools implements this principle, (claw hammer for striking and pulling nails; pencils for writing and erasing. Less time is required to reposition such a double-function tool than putting one and picking up another.

4. **Perform multiple operations simultaneously rather than sequentially**

- A work cycle is usually conceptualized as a sequence of steps, performed one after anther.
- Some times, steps can be done simultaneously with Special tooling and processes designed to accomplish multiple operations.

Con…

5. Hand tools and portable power tools should be designed for operator comfort & convenience

- For example, the tools should have handles or grips that are slightly compressible so that they can be held and used comfortably for the duration of the shift.

- ✓ The location of the handle or grip relative to the working end of the tool should be designed for maximum operator safety, convenience, and effectiveness of the tool. If possible, the tool should accommodate both right-handed and left handed workers.

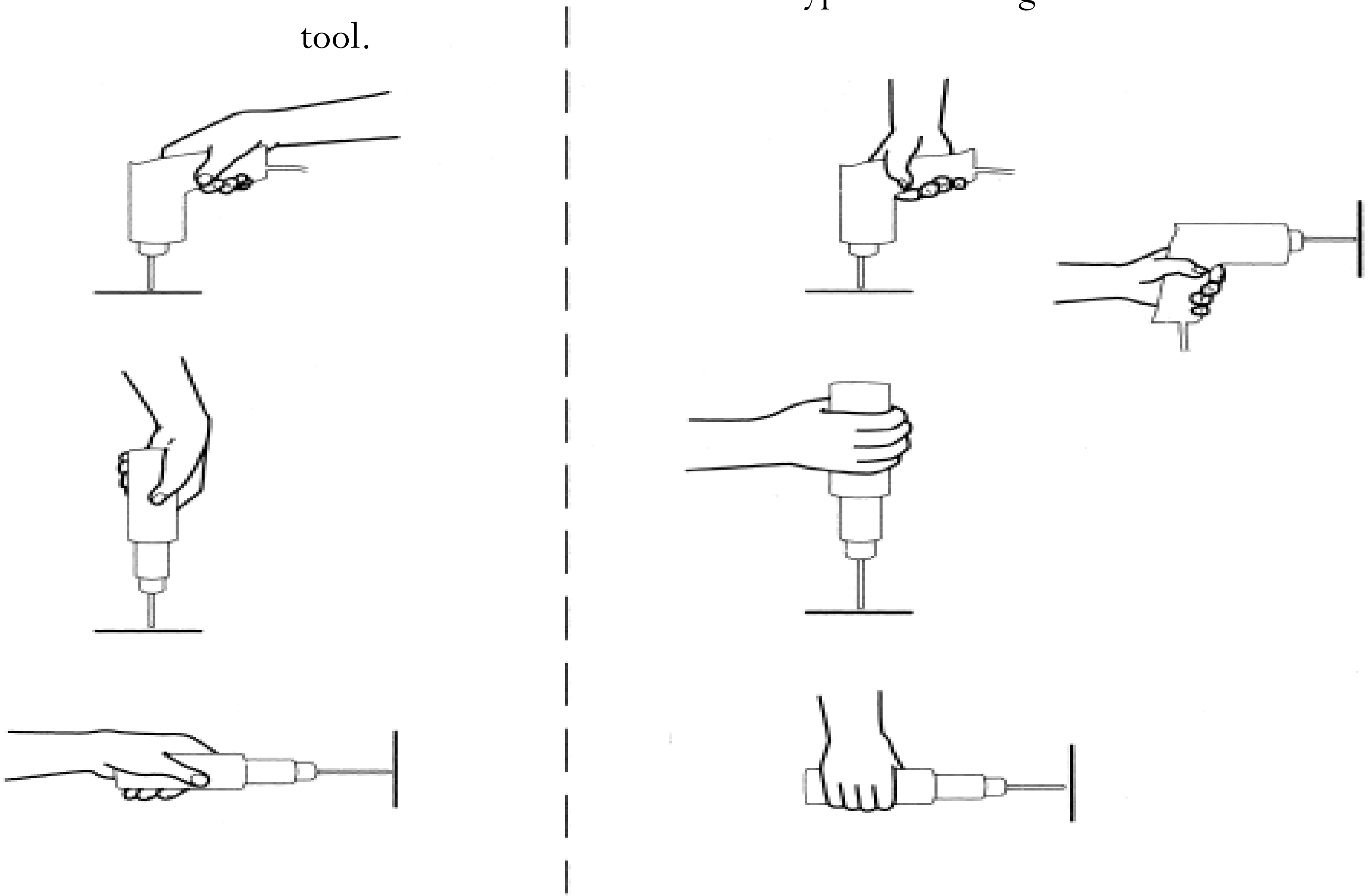
Con…

6. Locate All Control Devices for Best Operator Accessibility and Strength Capability

- Hand wheels, cranks, and levers should be of such a size and placed in such positions that operators can manipulate them with maximum proficiency minimum fatigue.
- Seated operators can apply maximum force to levers located at elbow level; standing operators, to levers located at shoulder height.
- Guidelines for crank and hand wheel radii are:
  - light loads, radii of 7.6-12.7 cm;
  - medium to heavy loads, radii of 10.2-17.8 cm;
  - very heavy loads, radii of more than 20 cm but not in excess of 51cm.

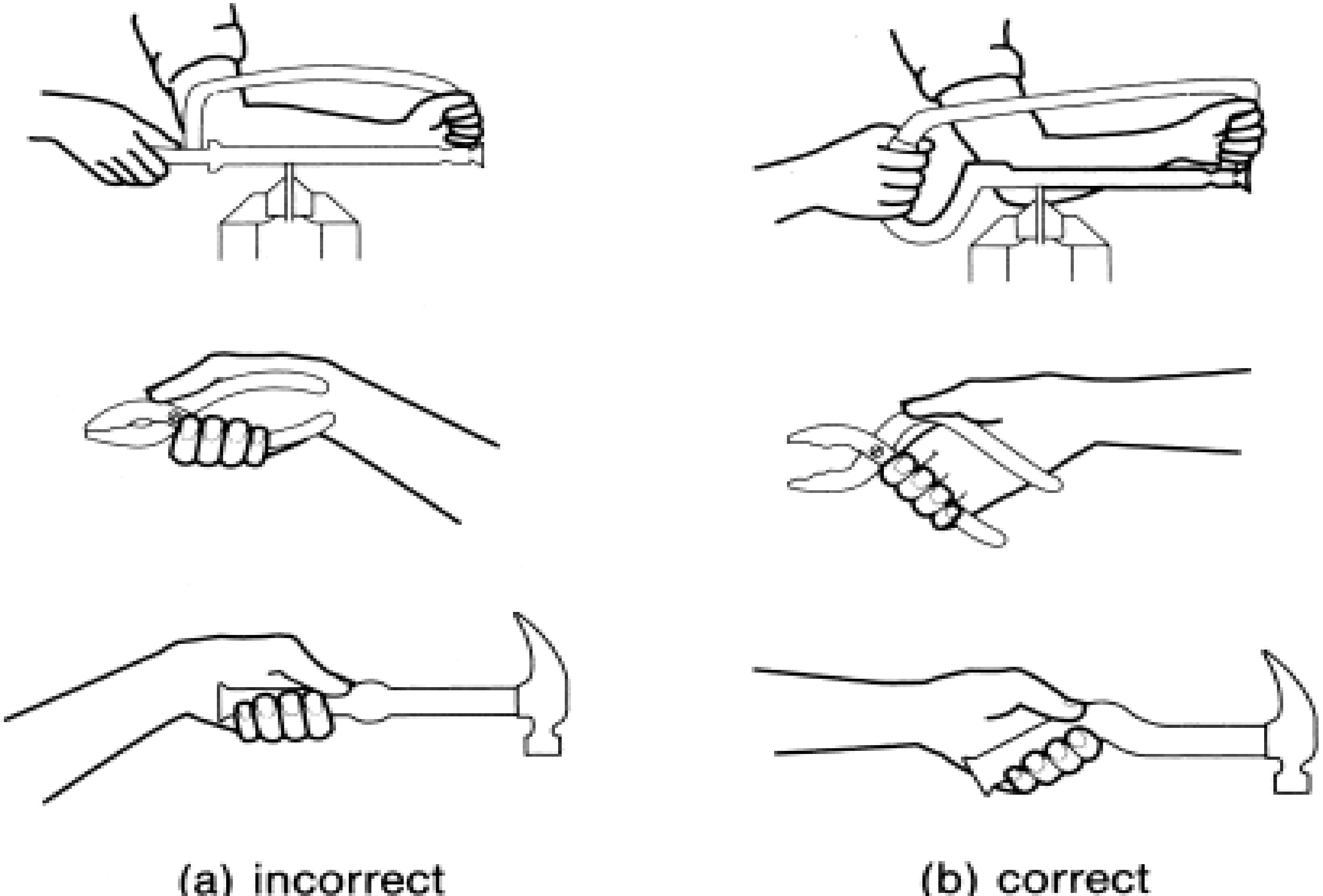
Example

When using hand-held tools, the wrist should be kept as straight as possible. The figure shows the correct and incorrect use of two types of rotating tool.



(a) incorrect (b) correct

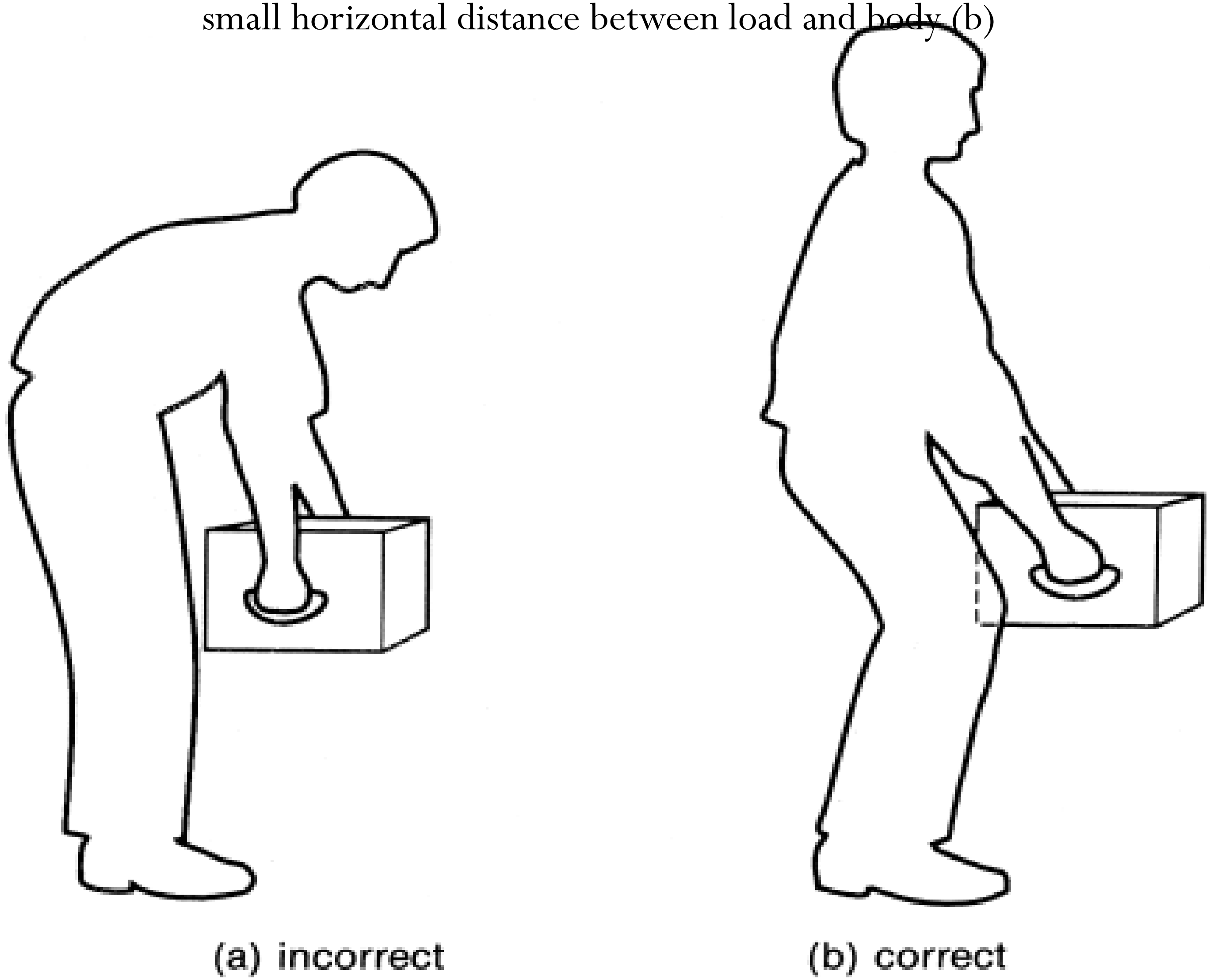
Con…



Correct location of handgrips on tools avoids having to bend the wrist.

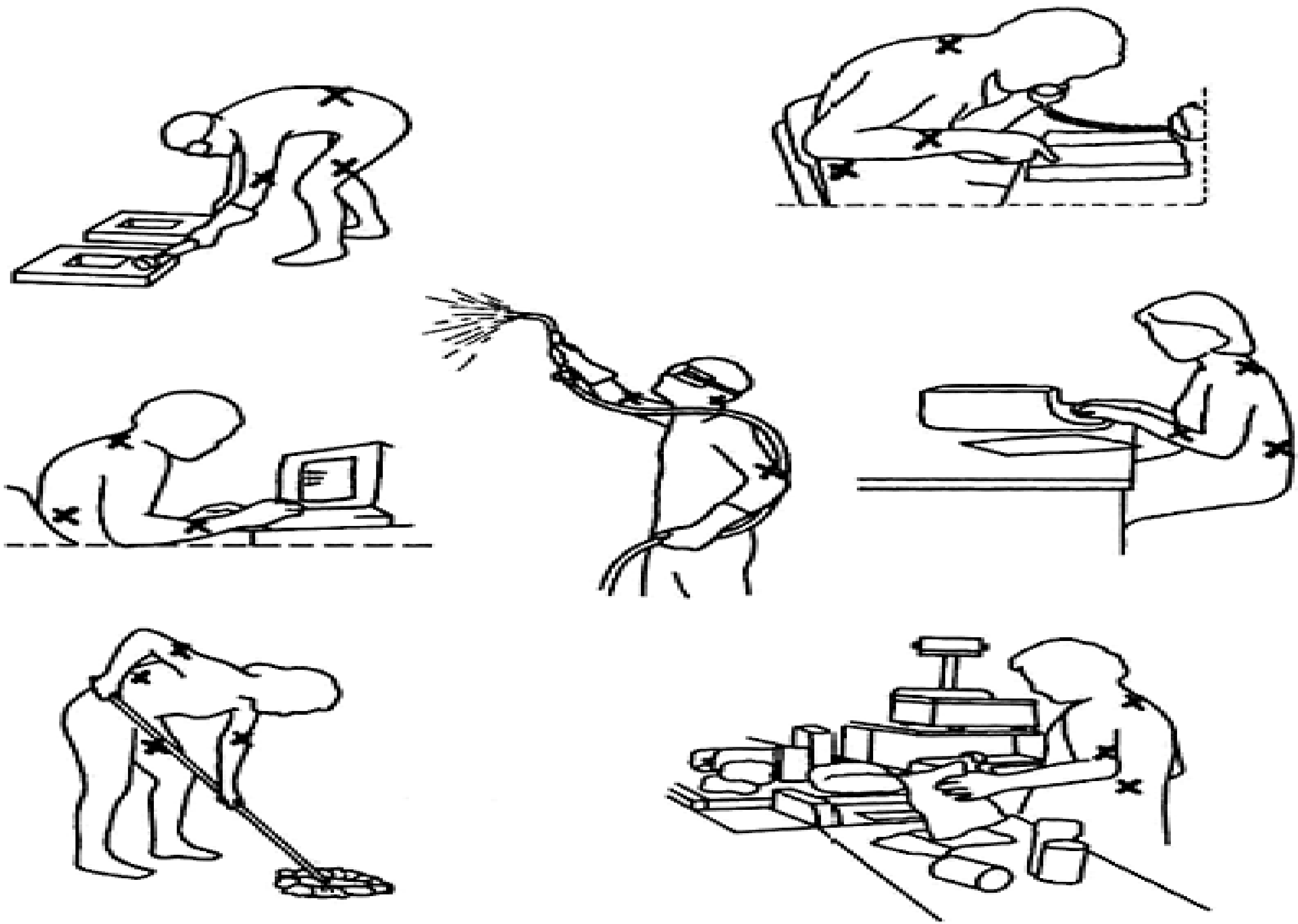
Con…

Lifting with a bent trunk and a large horizontal distance between load and lower back (a) is more hazardous than lifting with the back straight and a small horizontal distance between load and body (b)



Con…

Examples of work postures where there are problems with extreme joint angle, large muscular force, high degree of repetition, or high contact pressure



Manual Material Handling

- The term manual handling includes lifting, lowering, pushing, pulling, carrying, moving, holding and restraining, and encompasses a large part of the activities of working life.
- ‘any activity requiring the use of force exerted by a person to lift, lower, push, pull, carry, or otherwise move, hold or restrain any animate or inanimate object
- describes repetitive actions with or without force, sustained work postures, exposure to whole-body or hand-arm vibration, bending, twisting and reaching

Associated injuries

- The majority of problems arising from manual handling are associated with sprains and strains mainly of the back and neck
- However, other parts of the body are also affected most notably the shoulders, knees and ankles
- Injuries in these areas occur from different aspects of manual handling tasks such as overhead work (neck and shoulders), walking on rough ground or areas with difficult access (knees and ankles). Most manual handling injuries are cumulative, developing over many months or years of overload.

3.2 Issues in manual work design

I. The Human Musculoskeletal system

II. Principles of manual work design

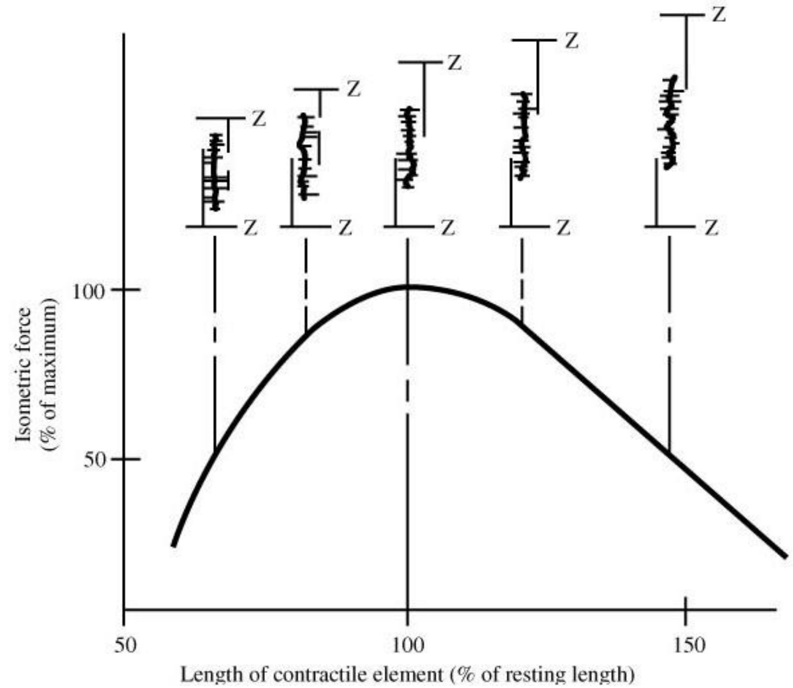
III. Motion Studies of manual work:
- Two-handed process charts
- Gilbreth's 17 basic therbligs

IV. Manual Work and Design Guidelines
- Energy expenditure
- Heart rate
- Lower back compressive forces
- NIOSH Lifting Guidelines

I. The Human Musculoskeletal system

Skeletal muscle

- Agonists: prime activators of motion
- Antagonists (oppose motion): counter act and oppose motion
- Role of muscle depends on type of movement
- Work can be designed to: make best use of human strength capabilities, and reduce injuries
- Muscle length can change from 50% (resting/ neutral) at complete contraction to 180 % of resting length at extension.



II. Principles of Manual Work Design

- Design work according to human capabilities and limitations.
- Design of Operations to fit Human Constraints.
- Introduced by Gilbreths through:
  - Principles of Motion Economy
  - Motion study
- **Motion study** **a**nalysis of the basic hand, arm, and body movements of workers *as they perform work*
- **Work design** designs the methods and motions used to perform a task

Motion Studies of manual work

- **Motion study** **a**nalysis of the basic hand, arm, and body movements of workers as they perform work
- **Work design** designs the methods and motions used to perform a task
  - Design of the work system
  - Includes:
    - Workplace layout and environment
    - Tooling and equipment used in the task such as workholders, fixtures, power tools, etc.

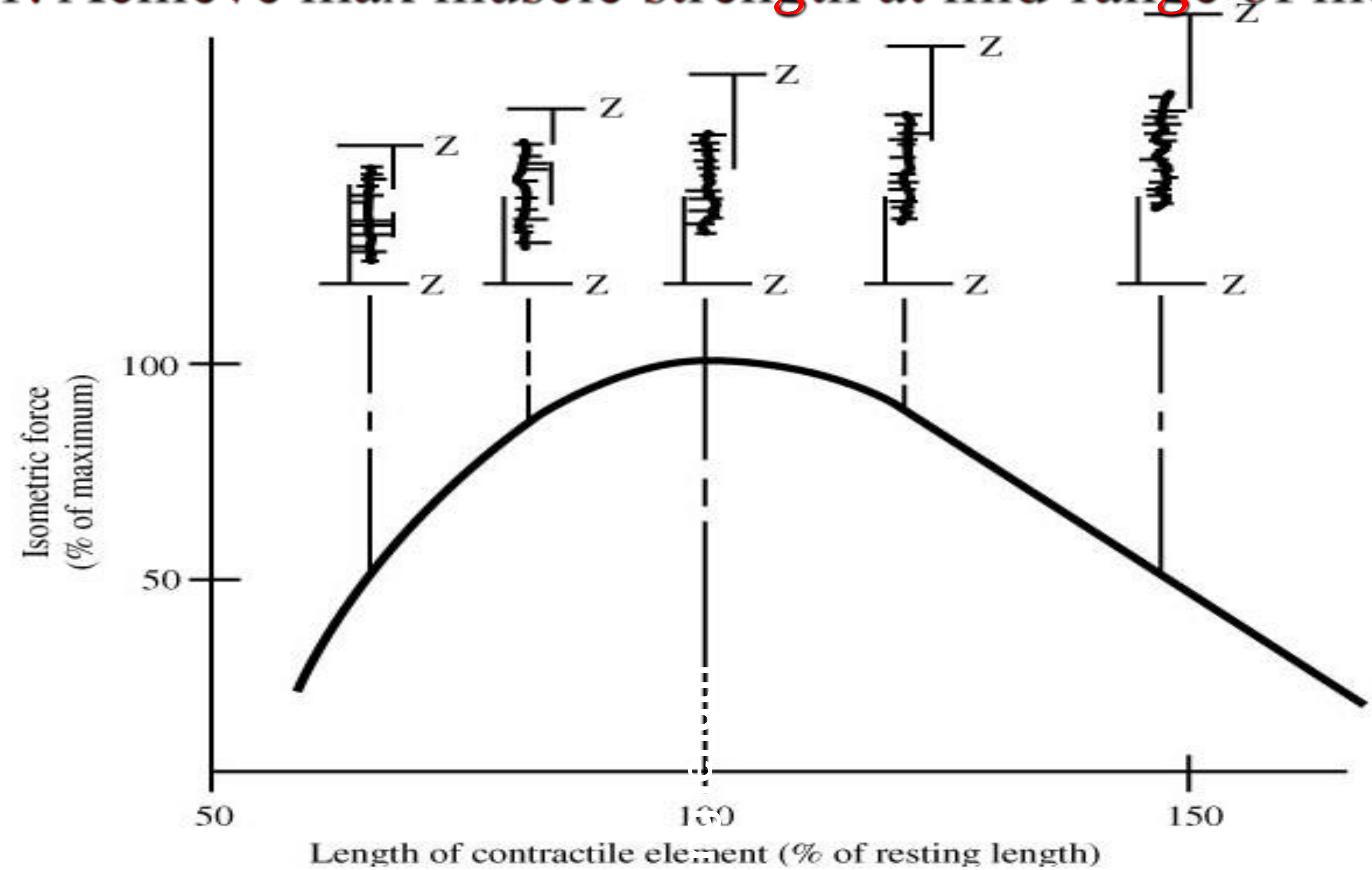
Principles of Work Design (Motion Economy)

1. Achieve max muscle strength at mid-range of motion
2. Achieve max muscle strength with slow movements
3. Use momentum to assist movements
4. Design tasks to optimize human strength capabilities
5. Stay below 15% of max muscle force
6. Use short, frequent work-rest cycles
7. Design tasks so that most workers can do them
8. Do not attempt precise movements immediately after heavy work

Principles of Work Design (cont.)

9. Use ballistic movements for speed
10. Begin and end motions with both hands simultaneously
11. Move hands symmetrically
12. Use natural tempo of body to set tempo of work
13. Use continuously curved motions
14. Use lowest practical classification of movement
15. Use low force for precise movements, fine control
16. Work with hands and feet simultaneously
17. Minimize eye fixations

1. Achieve max muscle strength at mid-range of motion



➢ *Tasks requiring considerable muscle force should be performed at the optimum position*

Example

- Straight position will provide the strongest grip strength for wrist motions.
- For elbow flexion, the strongest position would be with the elbow bent somewhat beyond the 90-degree position.
- A rough rule of thumb for finding the midrange of motion is to consider the posture assumed by an astronaut in weightless conditions when both agonist and antagonist muscles surrounding the joint are most relaxed and the limb attains a neutral position.

Typical relaxed posture assumed by people in weightless conditions

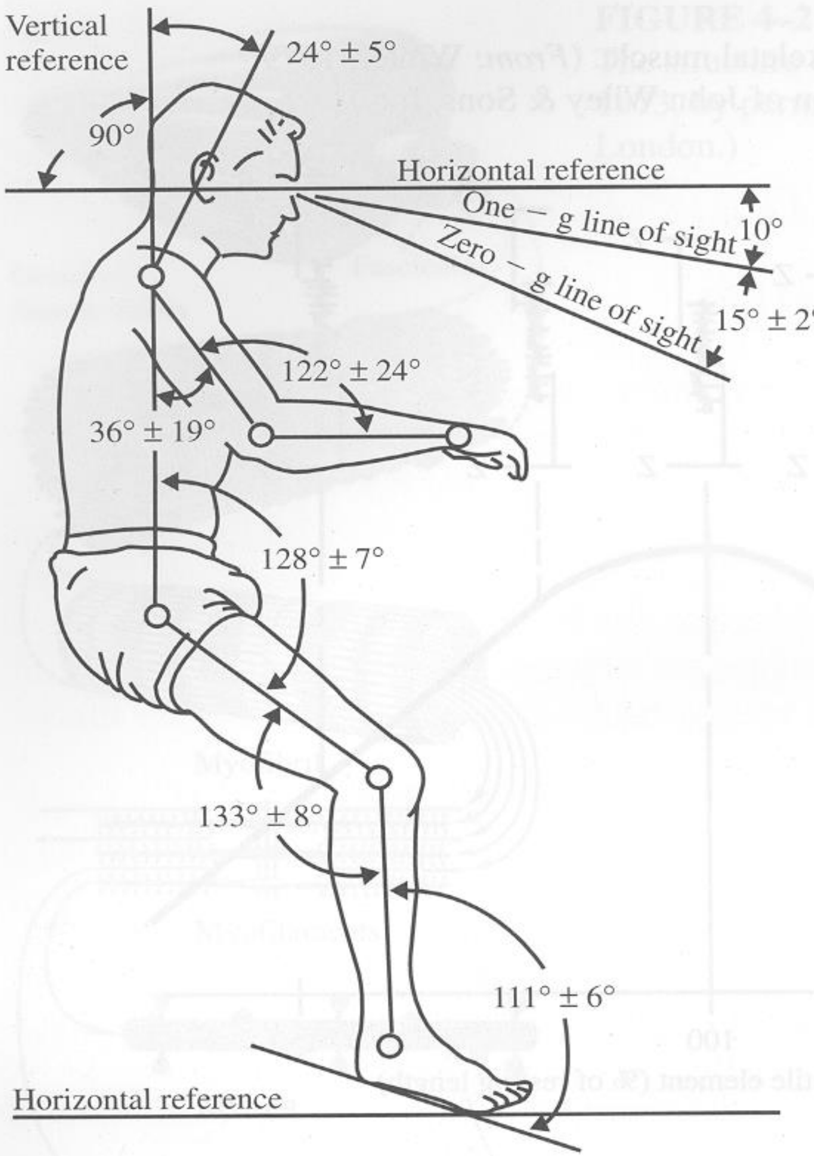


FIGURE 4–4 Typical relaxed posture assumed by people in weightless conditions. (*From:* Thornton, 1978, Fig. 16.)

2. Achieve the Maximum Muscle Strength with Slow Movements

- ➢Relevant for heavy manual work

- ➢At static contraction (with no externally measurable shortening) maximum force can be achieved

- ➢Minimum force is often produced at maximum velocity of muscle shortening

3. Use Momentum to Assist Movements

- Faster Movements Produce higher momentum & higher impact forces in case of blows
- Downward motions are more effective than upward motions, because of the assistance from gravity
- Example: When carpenters strike a nail with a hammer, they are using ***momentum***, which can be defined as mass times velocity. Imagine trying to apply a static force to press the nail into the wood.
- Example: operators to release a finished part into a delivery area while their hands are on their way to get component parts or tools to begin the next work cycle.
- Not all work situations provide an opportunity to use momentum as a carpenter uses a hammer, but if the opportunity is present, use it

4. Design Tasks to Optimize Human Strength

- Human strength capability depends on three major task factors: The type of strength
  - Dynamic Strength: muscle exertions resulting in body motions
  - Isometric Strength: where body motion is restrained

  ii. The muscle or joint motion being utilized

  iii. Posture

Isometric *Muscle strength* for sample Industrial Workers in different postures

Muscle Function	Joint Angles	Male (%ile)			Female (%ile)		
		5	**50**	**95**	**5**	**50**	**95**
Elbow flexion	90^o Included to arm (arm at side)	42	77	111	16	41	55
Elbow extension	70^0 Included to arm (arm at side)	31	46	67	9	27	39
Medial humeral (shoulder) rotation	90^0 Vertical shoulder (abducted)	28	52	83	9	21	33
Lateral humeral (shoulder) rotation	5^0 Vertical shoulder (at side)	23	33	51	13	19	28
Shoulder horizontal flexion	90^0 Vertical shoulder (abducted)	44	92	119	12	40	60
Shoulder horizontal extension	90^0 Vertical shoulder (abducted)	43	67	103	19	33	57
Shoulder vertical adduction	90^0 Vertical shoulder (abducted)	35	67	115	13	30	54
Shoulder vertical abduction	90^0 Vertical shoulder (abducted)	43	71	101	15	37	57

5. Use Large Muscles for Tasks Requiring Strength

- Muscle strength is directly proportional to the size of the muscle
- Therefore for instance; leg and trunk muscles should be used in heavy load lifting, rather than weaker arm muscles.

6. Stay Below 15 % of Maximum Voluntary Force

- Concerned with Muscle fatigue rate r
- The harder the muscle fiber contract, the faster the muscle fatigue
- Relationship b/n muscle force and endurance time is:

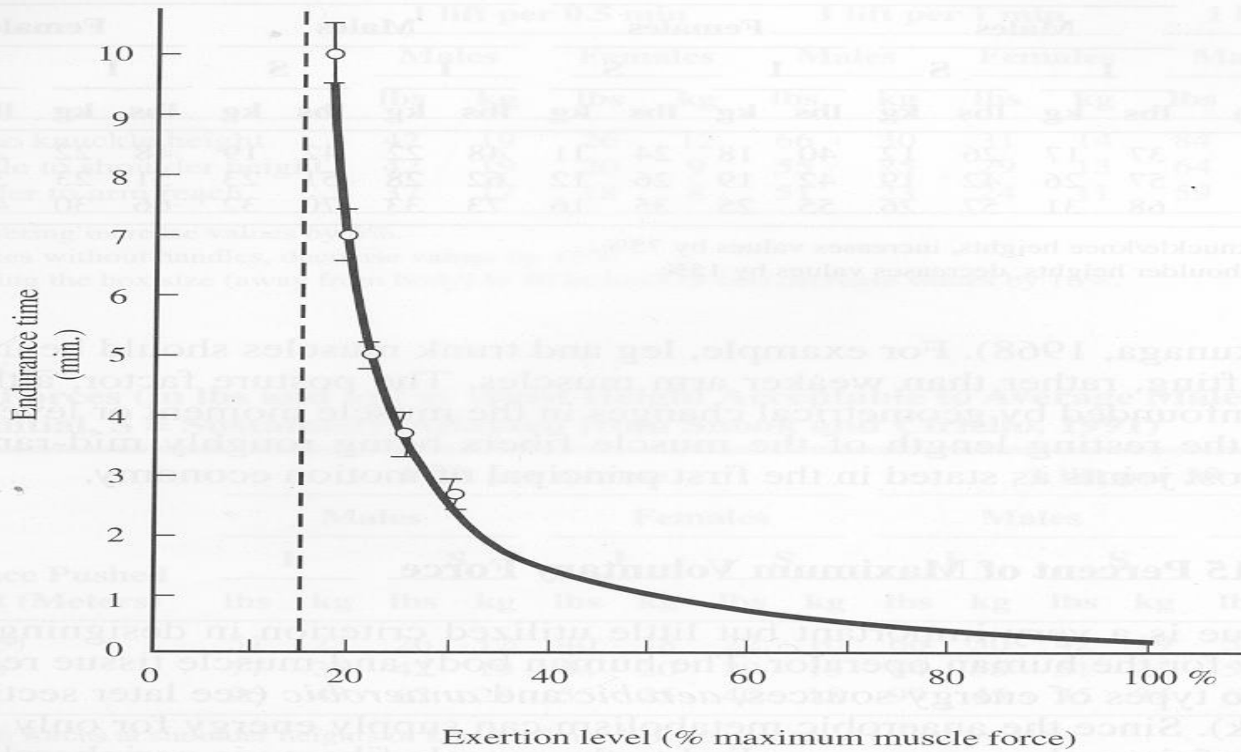
$$T = 1.2/(f - 0.15)^{0.618} - 1.21$$

where: T = endurance time (min)

f = required force, expressed as a fraction of maximum isometric strength

Static muscle endurance-exertion level relationship

FIGURE 4–7
Static muscle endurance–exertion level relationship with ±1 SD ranges depicted. (*From:* Chaffin and Andersson, 1991) (Reprinted by permission of John Wiley & Sons, Inc)



Example (Endurance time Calculation)

Suppose a worker would be able to sustain a force level of 50 % of Maximum strength for only about one minute:

$$T = 1.2/(0.5 - 0.15)^{0.618} - 1.21 = 1.09 \text{ min}$$

7. Use *lowest* practical classification of movement

High Speed & Precision

Low Force

- **1rst class**: *finger* motions,

  Example: typing, grasping small parts.

- **2nd class**: also *wrist* motions,

  Example: positioning a part

- **3rd class**: also *forearm* motions,

  Example: placing a small part in a bin

- **4th class**: also *upper arm* and *shoulder* motions,

  Example: reaching object on high shelf

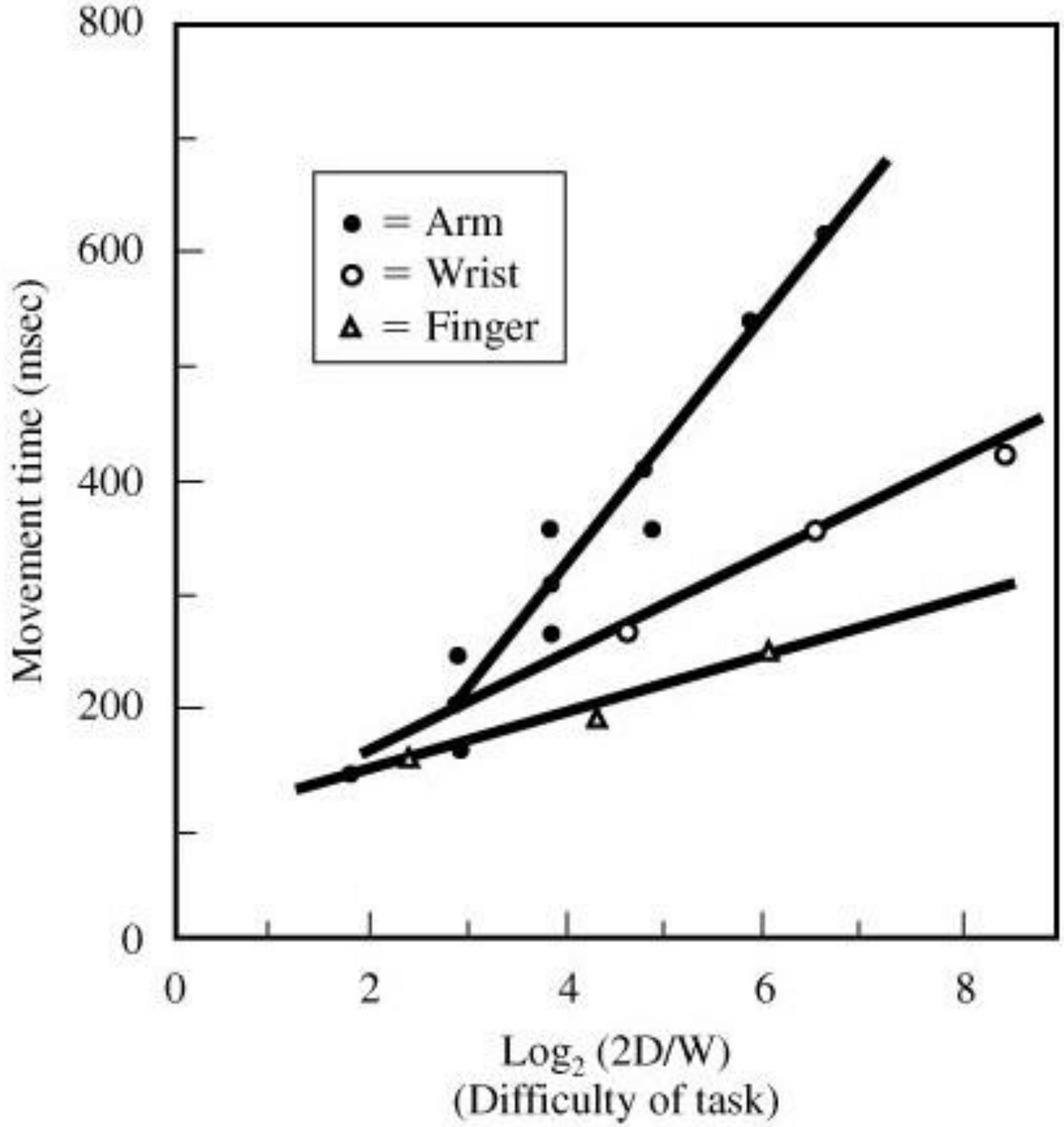
- **5th class**: *whole body* motions: leg, trunk,

  Example: lifting a heavy box.

Low Speed & Precision

High Force

Speed of 1rst, 2nd and 3rd Class Motions

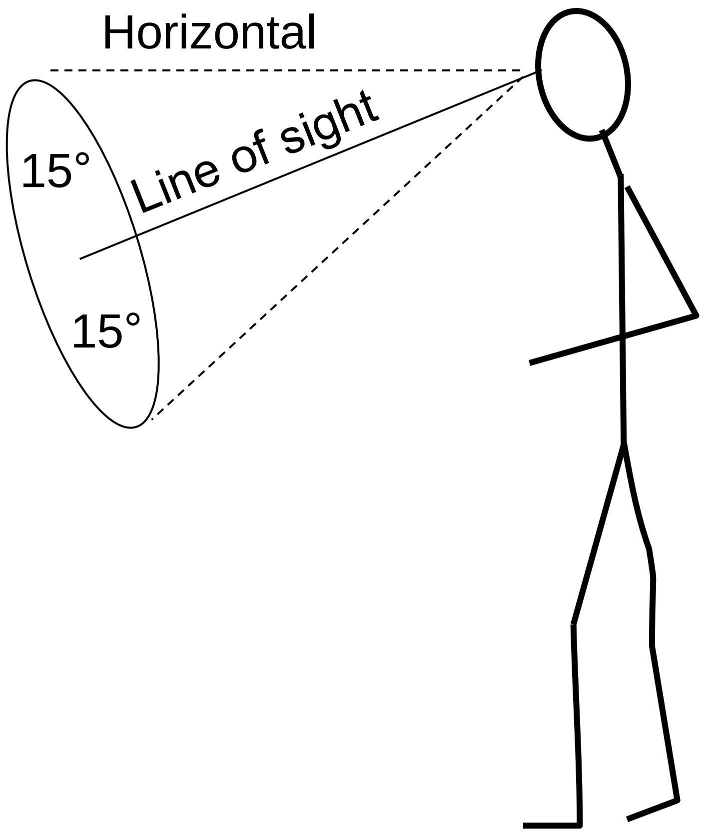


8. Work with Hands and Feet Simultaneously

- If operator is seated, consider using *foot pedals* to free hands.
- Examples:
  - Car controls include wheel and foot pedals for gas and brake,
  - Piano has both keys and foot pedals to modulate tone.
  - Machine may include a foot pedal to clamp and release part while operator positions it with hands.

9. Minimize Eye Fixations

- Normal line of sight is 15 degrees below horizontal,
- Visual field is defined by a cone,
- Head movements are *minimized* if eye fixations are limited to a single cone.



II. Motion Studies of manual work

- **Motion Study**: analysis of body motions while performing a job.
  - Two-handed process charts
  - Gilbreth's 17 basic therbligs
- Purpose: to Eliminate or reduce ineffective motions & facilitate effective movement

Gilbreths' 17 basic therbligs

- These 17 therbligs can describe *most* work.
  - **Effective:** advance work
  - **Ineffective**: do not advance work – consider whether they can be eliminated.

17 Basic Therbligs

Effective Therbligs

1. RE = Reach
2. M = Move
3. G = Grasp
4. RL = Release
5. PP = Pre-position
6. U = Use
7. A = Assemble
8. DA = Disassemble

Ineffective Therbligs

9. S = Search
10. SE = Select
11. P = Position
12. I = Inspect
13. PL = Plan
14. UD = Unavoidable delay
15. AD = Avoidable delay
16. R = Rest
17. H = Hold

Ineffective means: does not contribute directly to production.

Example: (Therbligs)

Therbligs	**E or I**	**Activity description**
Search	I	Look for wrench.
Grip	E	Pick up wrench.
Assemble	E	Tighten bolt in fixture.
Release	E	Place wrench on bench.
Delay	I	Clean safety glasses.
Use	E	Start machine.

Should one *always* use the 17 basic therbligs to describe work?

- Not always at the right level of *detail*, often work analysis is performed at a much higher level.
- Not always sufficiently descriptive, often need more *task-specific descriptions*.
- However, they can be useful for *categorizing* task-specific work elements.

Two-hand Process Chart

- Shows all movements and delays of left and right hands.
- Used for highly repetitive manual operations to identify ineffective motion patters which violates principles of motion economy.

Therbligs

Right Hand
Left Hand
Box Containing Pins

Box Containing Pins

Micro motion Analysis

- The main idea of method study at the therblig level: seeks to eliminate or reduce ineffective therbligs.
- Each therblig represents time and energy expended by a worker.
- If task is repetitive, this will be performed many times. Then, it becomes meaningul to analyze therbligs.
- Known as micromotion analysis

Micro motion Analysis

- Analysis of therbligs that make up a repetitive task
- Objectives:
  - Eliminate ineffective therbligs if possible
  - Avoid holding objects with hand – Use workholder
  - Combine therbligs – Perform right-hand and left-hand motions simultaneously
  - Simplify overall method
  - Reduce time for a motion, e.g., shorten distance
- Checklists:
  - Checklist1 (discussed in the in class)
  - Checklist2 (given in the book – Table 10.3)

III. Manal Work and Design Guidelines

- Energy expenditure
- Heart rate
- Lower back compressive forces
- NIOSH Lifting Guidelines

Energy Expenditure

- 5.33 kcal/min for men, 4 kcal/min for women, is a limit for acceptable average energy expenditure over an 8 hr day
- Since energy expenditure produces lactic acid , carbon dioxide and heat, sufficient recovery time must be provided to recycle the produced lactic acid.
- Energy expenditure can be measured by oxygen consumption: compare O_2 in air inhaled vs. O_2 in air exhaled.

  $E(kcal/min) = 4.9 * V\ (0.21 - Eo_2)$

where: E = energy expenditure (kcal/min).

V = volume of air inspired (liters/min).

Eo_2 = fraction of oxygen (°2) in expired air (roughly 0.16-0.18).

Heart Rate

- 5.33 kcal/min work load produces 40 beat/min
- **Heart rate** should not be allowed to increase more than 40 beats/minute during work over resting pulse.
- **Heart rate creep**:
  - Watch for a gradually increasing heart rate.
  - If heart rate keeps going up then worker is not getting sufficient rest: fatigue is increasing.
- Factors that impact heart rate and fatigue:
  - Physical workload
  - Heat
  - Mental stress (e.g. air traffic control)

Rest Cycles: How much is needed?

- Rest may be needed if:
  - Average energy expenditure is too high,
  - Heart rate is too high,
  - Environment is too hot to allow body to rid its self of heat
- Short, frequent rest cycles are best

$$R = (W - 5.33) / (W - 1.33)$$

R = Time required for rest as % of total time spent working
W = Average energy expenditure for task (from Fig. 4-20, pg 157)
5.33 kcal/min is max allowable energy expenditure for *men*, (4 kcal/min for women)
1.33 kcal/min is the energy expended during rest.

Example: work/rest cycles

- *Estimate* how much rest needed for an average male performing a shoveling task:
  - Task: shoveling dirt; with approximately 16 lb in each shovel.
  - Energy expenditure = W = 8.5 kcal/min (fromFigure 4-20)
  - Percent rest required =

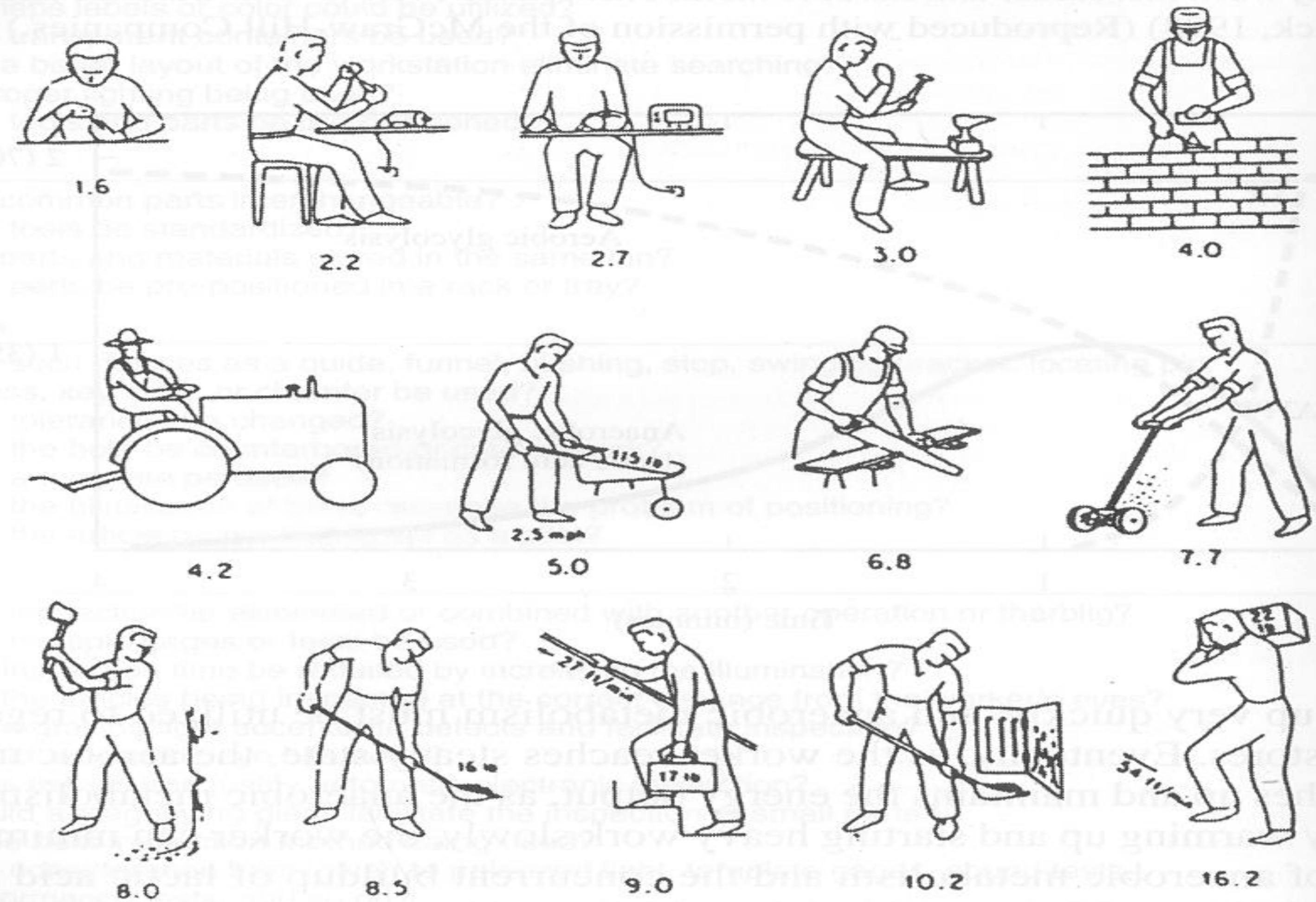
    R = (W – 5.33) / (W – 1.33) =

    = (8.5 kcal/min – 5.33) / (8.5 kcal/min – 1.33)

    = .414 (e.g. 41 percent of the time needs to be rest).
- This means that workers should rest approximately 25 minutes out of every hour.

Energy Costs of various types of Human activity(kcal/min)

FIGURE 4–20
Examples of energy costs of various types of human activity. Energy costs are given in kilocalories per minute. (*From:* Sanders & McCormick, 1993) (Reproduced with permission of the McGraw-Hill Companies.)



Example (cont.)

- Is it better to give workers …?
  - 1.7 hour breaks out of every 4 hours, (2 long breaks per day)

  \- 8 minutes breaks out of every 20 minutes (many short breaks per day)

Lower Back Compressive Forces

- Total force on disc L5, S1 (in lower back) should not exceed 770 lb (Danger of threshold)
- The total force on the spine is the sum of:
  - Force exerted by spine muscles to counter balance torque,
  - Force exerted by load.

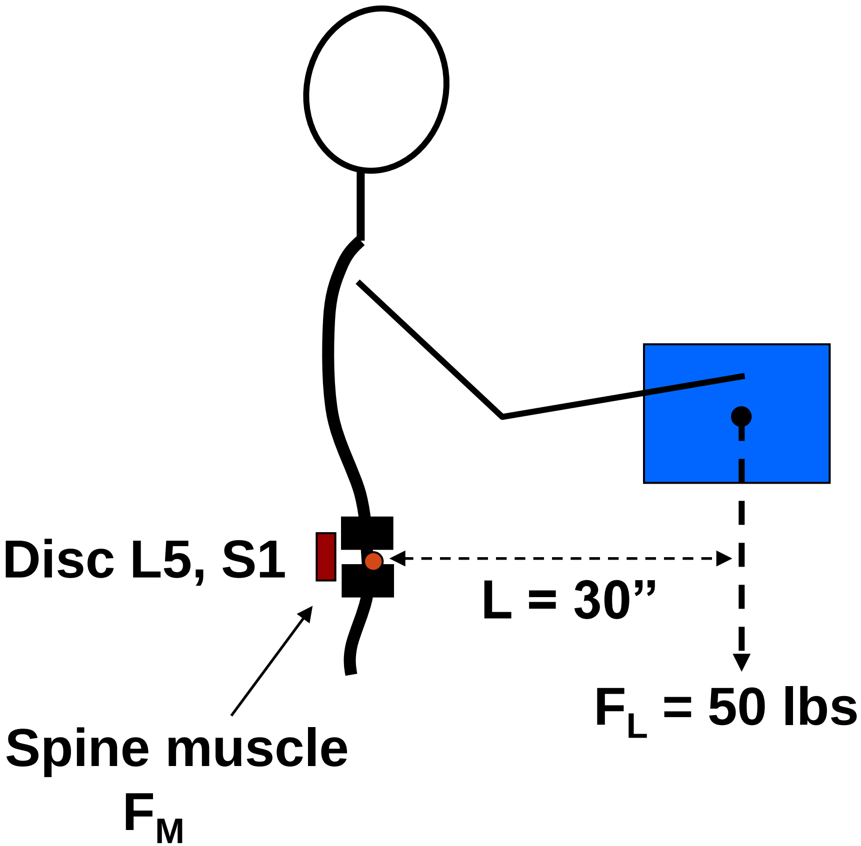
$$F_{COMP} = F_M + F_L$$

Spine muscle force

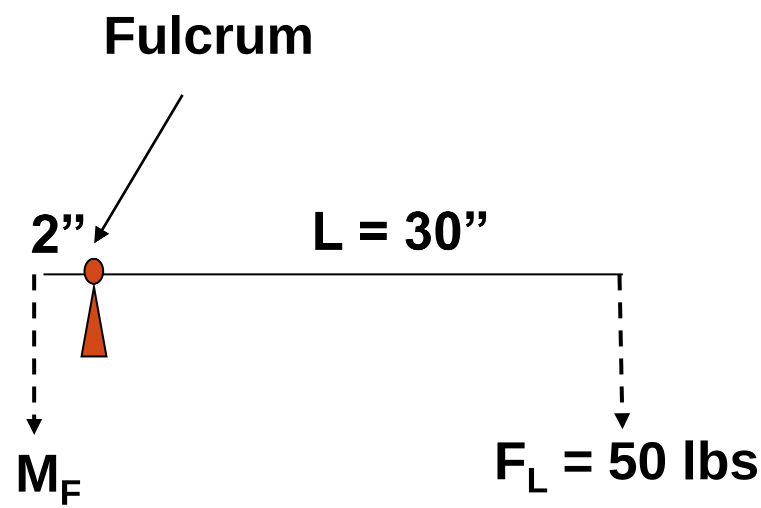
Weight of the load

Total compressive force on spine

Model the Lower Back as a *two lever* system to find spine muscle force, M_F



The moments must be equal:



$$2'' \times F_M = L \times F_L$$

$$F_M = (30'' \times 50 \text{ lbs}) / 2'' = 750 \text{ lbs}$$

Lower Back Forces: example

- Let W = 50 lb
- Let L (length of lever arm) = 30”

1. Find M_F (muscle force)

F_M = (L x F_L) / 2”

= (30” x 50 lb) / 2” = 750 lbs

2. Find F_{COMP} (total compressive force)

F_{COMP} = F_M + F_L = 750 lb + 50 lb = 800 lb

Which is greater then 770 lb; Is this OK for worker’s health?

NIOSH Lifting Guidelines

- NIOSH: National Institute for Occupational Safety and Health.
- Defines RWL: Recommended Weight Limit(load that can be handled by almost every one)

- Defines loads that can be handled by "*most young healthy workers*"
  - Ok for lower back (770 lb of *stress* or less)
  - 75% women, 99% of men have *strength* to lift load
  - Max *energy* expenditure of 4.7 kcal/min or less
- LI = Lifting Index = Load Weight/RWL

  LI exceeding 1.0 may be hazardous.

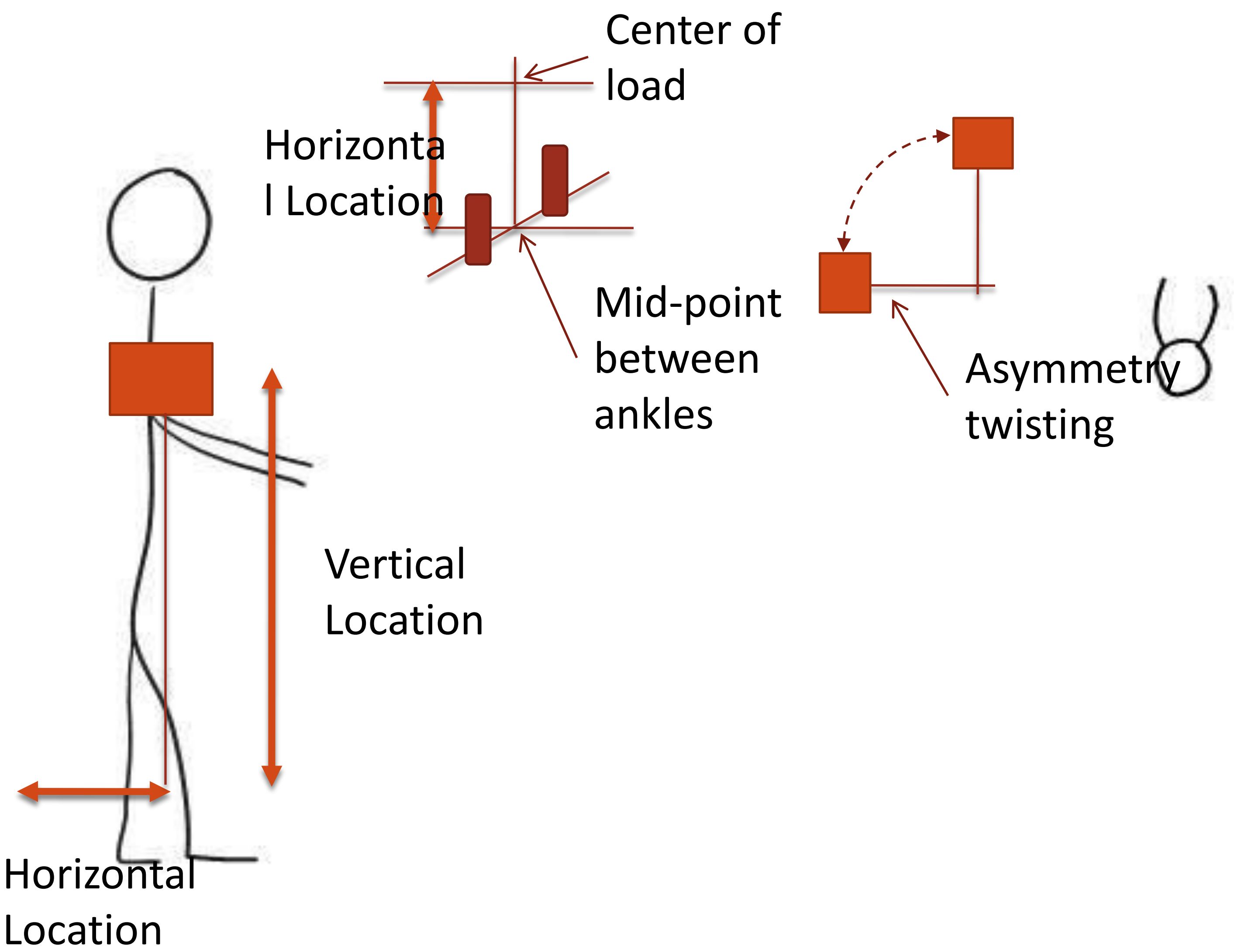
Additional Factors that can effect likelihood of back injury

- Amount of twisting in lift
- Presence of old injuries and scaring,
- Congenital spine defects
- Ageing: osteoporosis (bone fracture)

NIOSH Lifting Equation

- Compares initial location of load to final location
- Rating: Lifting Index
- Considers:
  - Posture
  - Duration
  - Frequency
  - Position of the load
  - Asymmetry (twisting)
  - Weight/force of the load
  - Coupling

NIOSH LIFTING EQUATION FIGURE



NIOSH Lifting Guidelines

Recommended Weight Limit

Horizontal Distance between load center and body center

Vertical *starting* location of load; e.g. height off of ground

Total vertical distance traveled between start and finish of lift.

RWL = LC * 10/H * [1 - .0075 | V – 30 |] * [0.82 + 1/8/D] * [1 – 0.0032*A] * FM * CM

Load Constant = 51 lb

Angle of “twist”

Frequency Multiplier (From Table 4 -7, pg 167)

Coupling Multiplier (From Table 4 – 8, pg. 168)

NIOSH Lifting Example

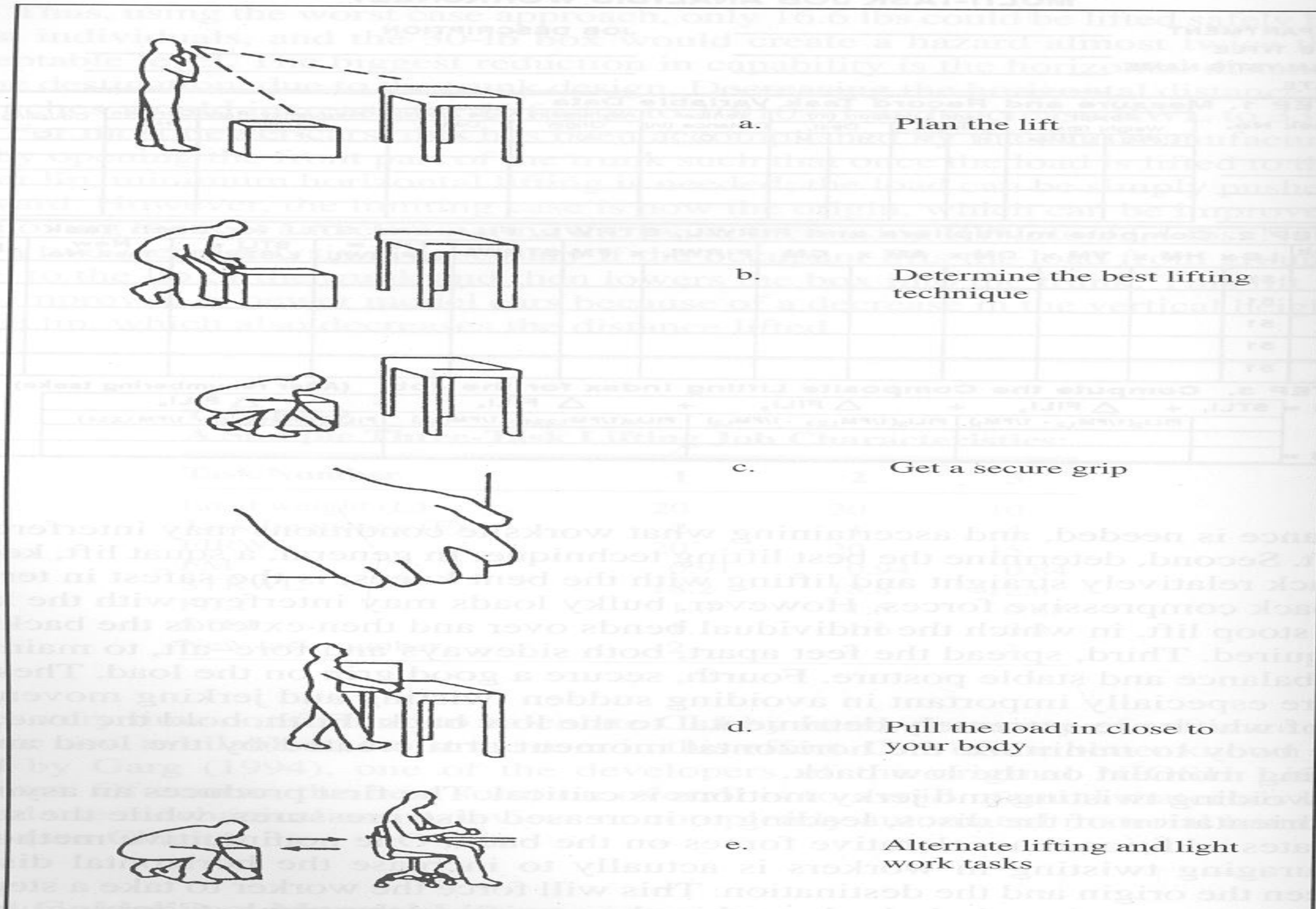
- Single lift:
  - Lift 30 lb box from ground (V = 0”) onto a 25” high table (D = 25”).
  - Worker must twist 90 degrees to get box on table (A = 90 degrees)
  - The box must be held out 10” from the body center to get it on the table (H = 10”)
  - Assume this is a one-time lift (FM = 1)
  - The box is small and compact but has no handles (coupling is fair = 0.95)

RWL = 51 (10/10) (1 - .0075 |0 – 30|) (0.82 + 1.8/25) (1 – 0.0032*90) (1) (0.95) = 23.8

LI = W/RWL = 30/23.8 = 1.26

Is this potentially hazardous?

FIGURE 4–30
Safe lifting procedure. (Available through S.H. Rodgers, Ph.D. P.O. Box 23446, Rochester, N.Y. 14692)



Guidelines for lifting. Five guidelines for performing manual lifting tasks are illustrated. See the text for further discussion.

NIOSH Lifting Equation Example

- Refer to video and NIOSH Lifting Equation in your workbook

$LI < 1$ → Safe

$1 < LI < 3$ → Increased Risk

$LI > 3$ → Not Safe

When using the NIOSH lifting equation
no worker should be performing a task with
a lifting index greater than ***3!***

THANK YOU…!!