Cost and Benefit Analysis of Anthropometric Data

Car Height Design:

_Mean sitting height for males: is 90cm with a standard deviation of 5cm,

_A ceiling height of 91cm (measured from the seat) will accommodate 50% of drivers with 1cm clearance to allow for hair or clothing (except hats).

_An increase in ceiling height of 5cm will accommodate a further 34% of drivers so that a total of 84% are now catered for.

_A further increase of 5cm will accommodate an extra 14% of drivers bringing the total to 98%.

_However, a further increase of 5cm will only accommodate an extra 2% of drivers in the population.

The designers of a new ship for use by a British crew wish to specify the minimum deck height to allow sufficient headroom for the crew. The ship will be built in 2 years' time and will be in service for 30 years. Assume a stature increase due to the secular trend of 1.5mm/year and recommend an appropriate height, DH.

- DH = SH*x* + *CA* + *DA* + *STA(Yt - Yb)* + *PA**
- where
- DH = deck height
- SH*x* = *x percentile stature*
- *CA = clothing allowance (shoes, helmets, when worn) = 70mm*
- *DA = dynamic allowance (accommodates head movements when walking)*
- = 100mm
- STA = secular trend allowance = 1.5mm/year
- Yt = target year for specifying deck height = 2035
- Yb = Base year (in which the height data were captured) = 1986
- PA = Psychological allowance (perception of head room) = 50mm

Application of Anthropometric Data

WORK SPACES

Chapter 13

McCormick and Sanders

- Work space envelopes:

–It means the 3 dimensional space within which an individual works. (e.g. the space within which the hands are used.)

- Related to the concept of work space envelopes:

– Out-of- reach requirements

- The distances required to prevent a person from reaching something (Usually hazardous) over a barrier.

– Clearance requirements

- The minimum space needed to move through a tight space or perform work in a confined area.

Work-space envelopes for seated personnel

- It is Determined by functional arm reach –

  which is influenced by

  i. Direction of arm reach

  ii. Nature of the manual activity (e.g. the task or function) to be performed.

  iii. Presence of restraints on work-space envelope.

  iv. Effects of apparel worn

1. Effects of direction of reach and Presence of Restraints on Work Space Envelope:

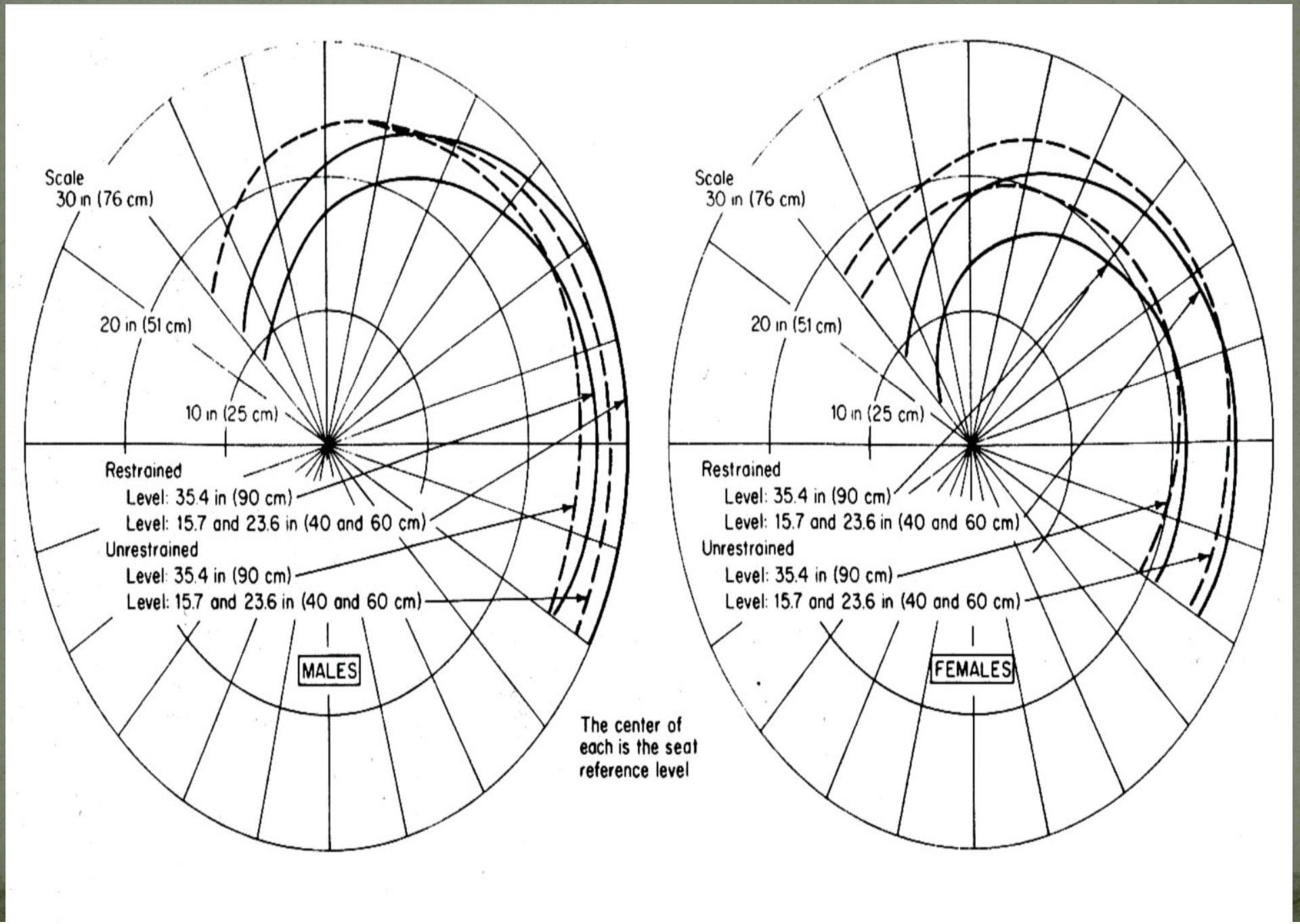
STUDY 1:

Results based on the study (Roth, Ayoub,& Halcomb, 1977) –

They measured the functional arm reach of subjects at

- Various lateral angles from a dead-ahead seated position (from -45°left to +120°right) and at various levels (ranging form -60°to 90°) from a seat reference point (SRP).
- Measurements were taken of the "grip-center" reach point at 114 such locations, under both restrained and unrestrained conditions.
  - In the restrained conditions
    The shoulders were held back against the seat back
  - In the unrestrained conditions
    The subjects could move their shoulders.

Results: 5th Percentile Male and Female



Study 2

- – The type of restraint can influence the functional arm reach.
- • Based on study of comparing three types of vehicle seat restraint (Garg, Bakken, and Saxena,1982).

  Lap Belt: Furthest Reach

  Cross Harness Belt: Reducing 14%

  Parallel Harness Belt: Reducing 24%
- • The less the restriction, the further the reach.

2. Effects of manual activity

- Manual Activity Influences the boundaries of the W/S envelope.

  Example:

  Push Button Activity: Finger Tip Measurement

  Use Knobs/Grasp Lever: Thumb Tip Measurement

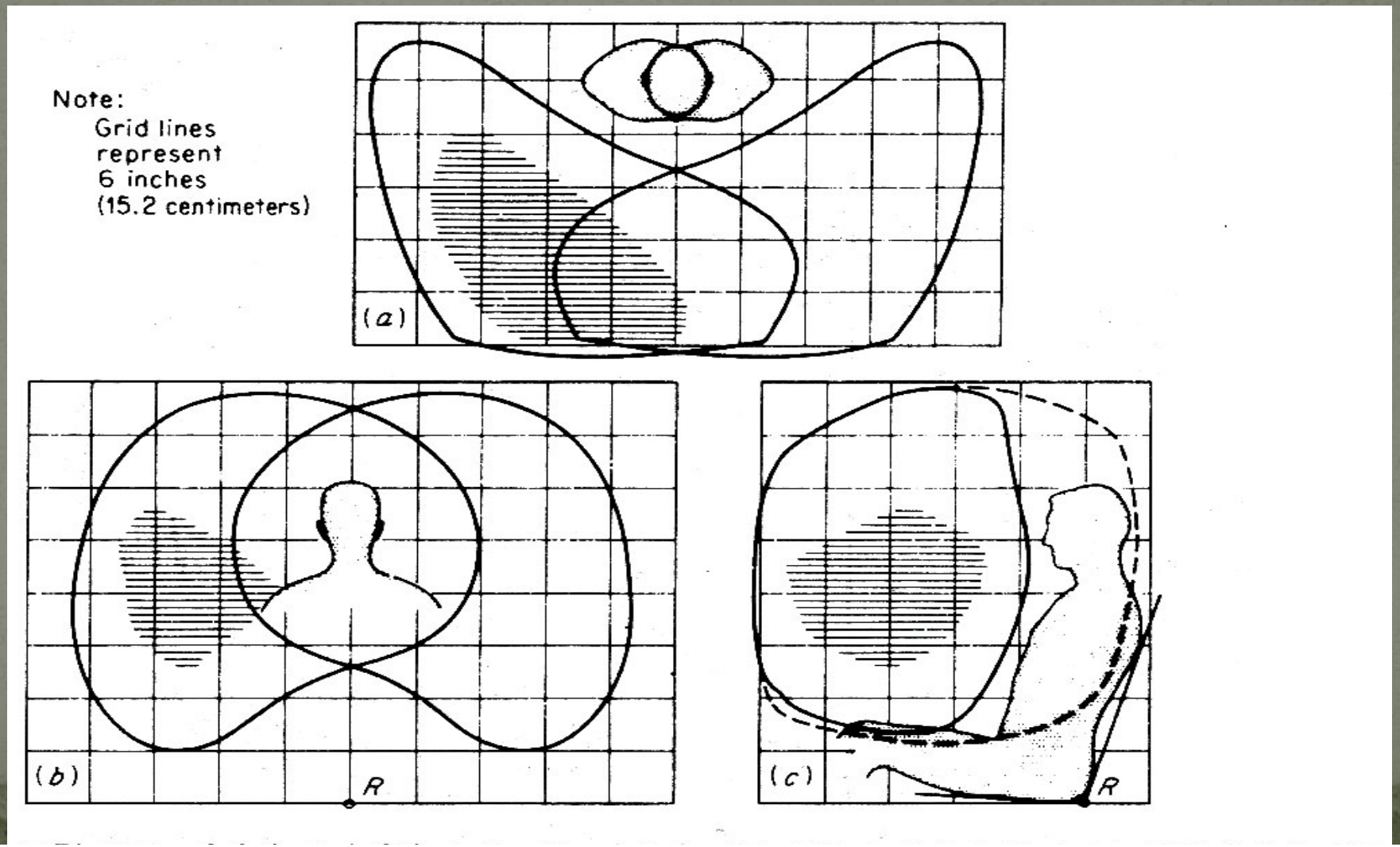
Bullock(1974)

– thumb tip measurement are about 2 in or more shorter than finger tip measurements.

- Different hand grasp actions influence the space envelope

• Dempster's (1955) study involved grasping a handle like device with the hand in 1 of 8 fixed orientations (Supine, prone, inverted, and at five spatial angles). Photographic traces of contours of the hand and the movement.

- Kinetoshere is developed for each grasp, showing mean of three angles: top (transverse), front (coronal), and side (sagittal).
- The shaded areas indicates the various types of hand grips could most adequately be executed by people.



3. Effects of apparel on W/S Envelope:

- The apparel worn by people can restrict their movements and the distances they can reach.
- Winter jackets restricted reach by 2 in (Sanders 1977).

Work-space envelopes for standing personnel

- Standing reach is a matter of body equilibrium and the reach envelop will be modified by any factor affecting this.
- Reach is diminished if a weight is carried in reaching hand or
- If an obstacle is placed behind a person that limits counterbalancing activities.
- Reach is increasing by increasing the base of the feet.

The Zone of Convenient Reach (ZCR)

(Pheasant,1986). ZCR as the space in which an object may be reached within arm's reach.

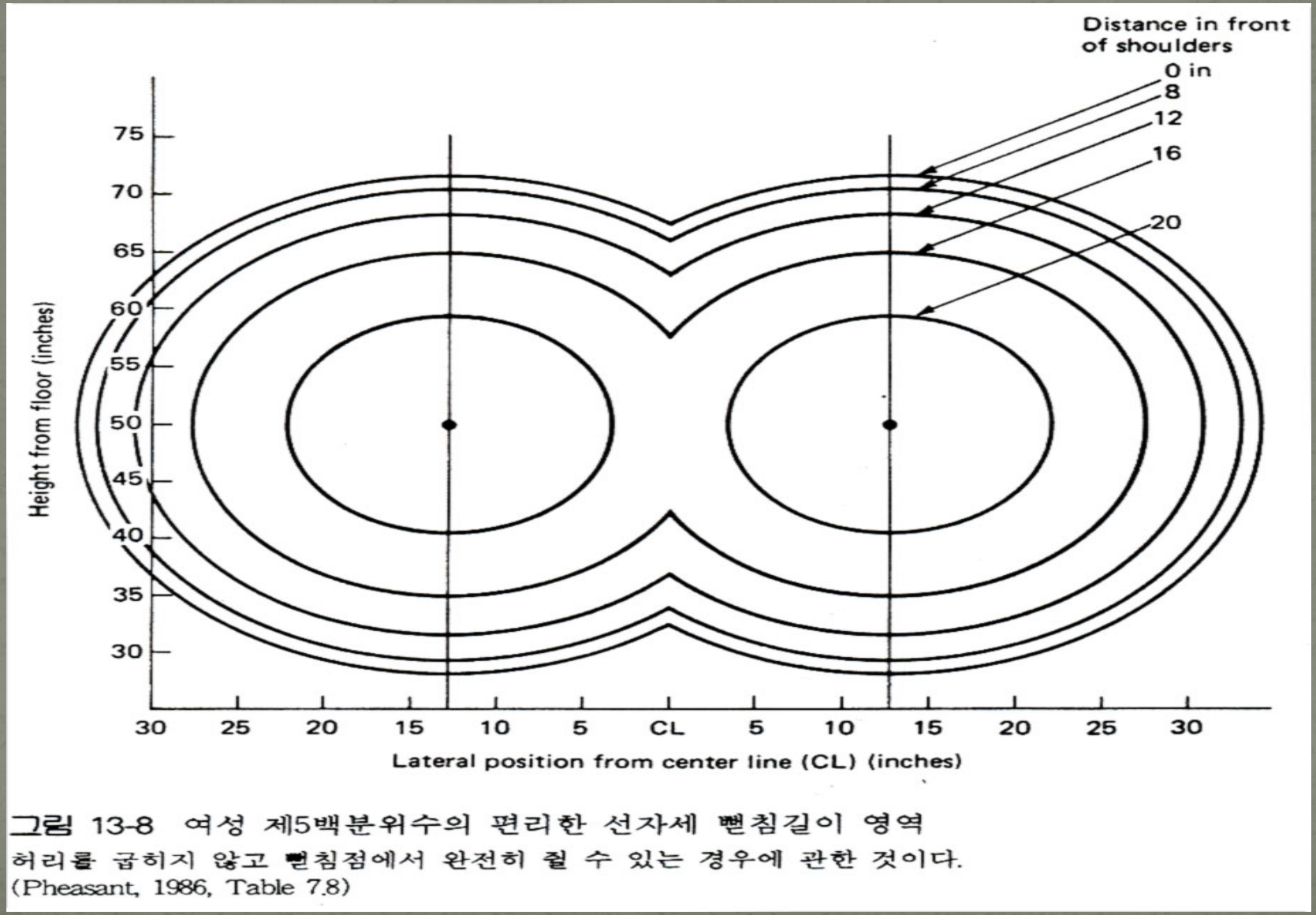


그림 13-8 여성 제5백분위수의 편리한 선자세 뻗침길이 영역
허리를 굽히지 않고 뻗침점에서 완전히 쥘 수 있는 경우에 관한 것이다.
(Pheasant, 1986, Table 7.8)

- **Discussion of Work-space envelopes**

– The reasonable limits of such space are determined by "functional arm reach"

– Functional arm reach is influenced by such variables as:

  - Direction of arm reach
  - The nature of the manual activity
  - The use of restraints
  - Apparel worn
  - The angle of the backrest
  - Personal variables such as age, ethnic group, and handicaps.

– Design such space for the 5 percentile of the using population, thus making it suitable for 95 percent of population.

- Consider special populations the design of the work space requires particular attention.

Design: Out of reach

- Out of reach requirements

– Things not to be touched (e.g. children play room)

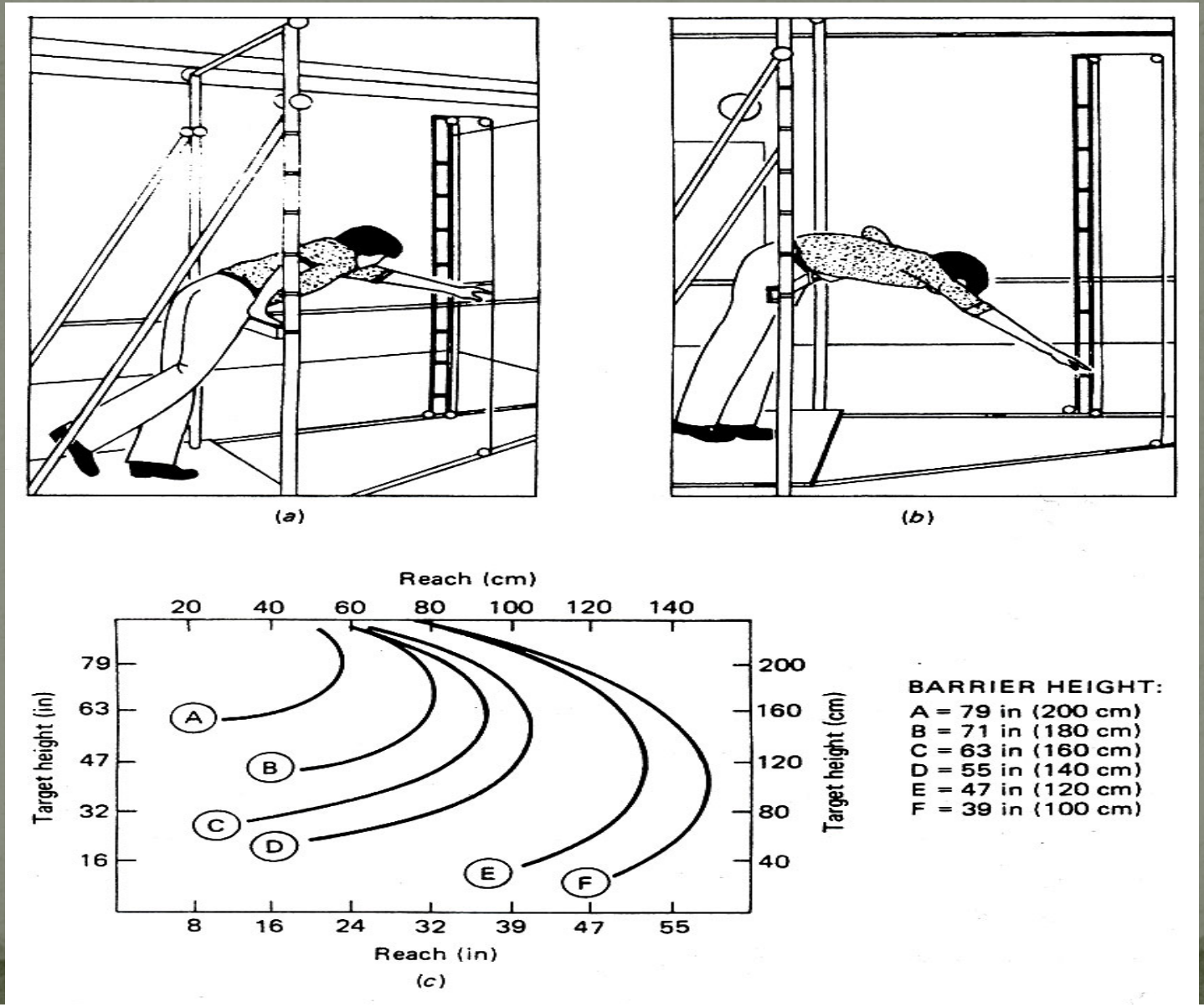
– Design space, a barrier of some height is place between the person and the object.

– How far? It depends on:

1) the height of the barrier

2) the height of the object.

– Example: Thompson (1989) using males of the 99th percentile in stature measured maximum reach for various combinations of these two variables (see Sanders, Figure 13-9, p. 430).

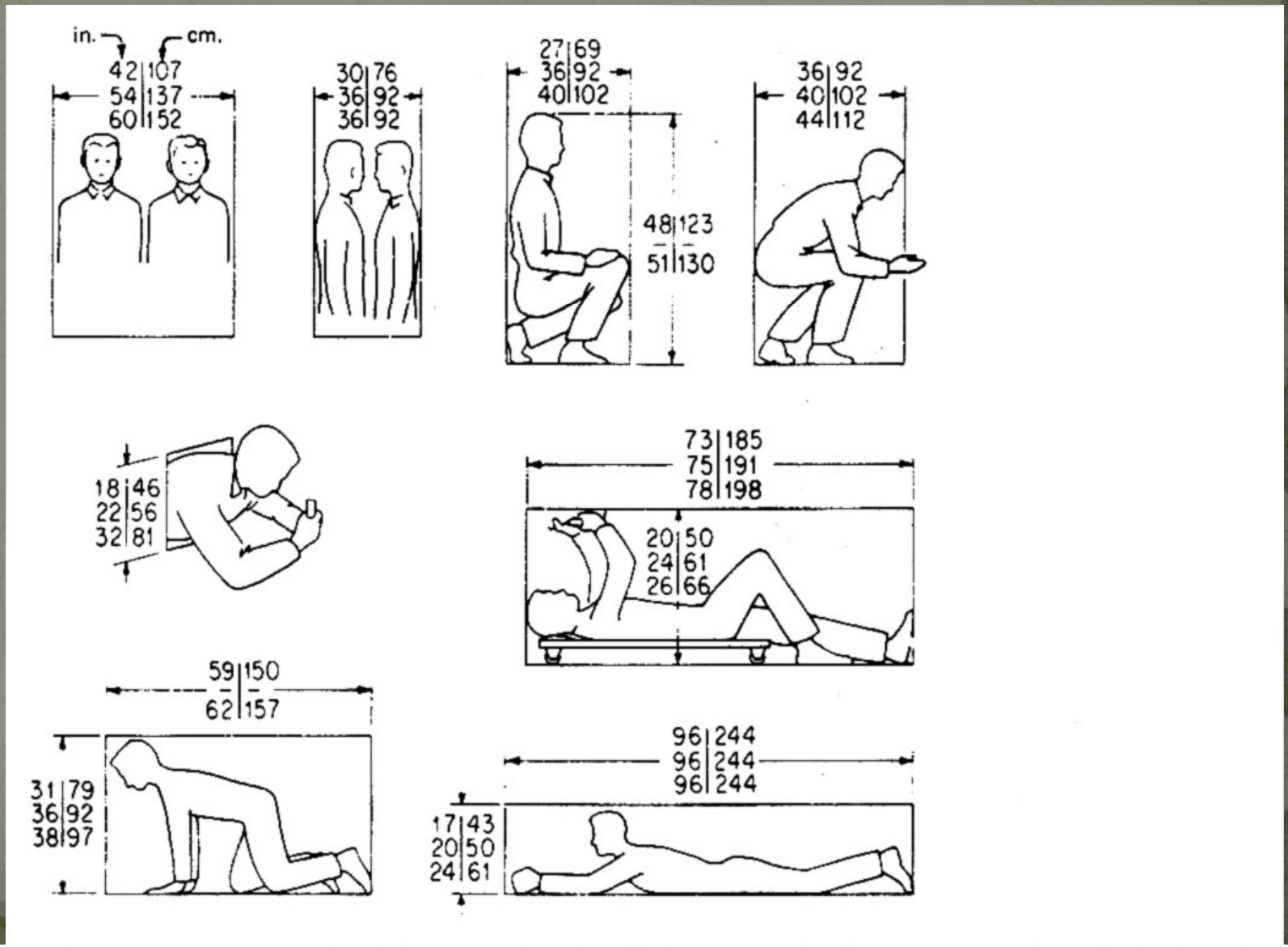


Design: Clearance

- Clearance requirements

– Move through, work in, or just fit into spaces.

- Example:



- Sanders(1980) reports the dimensions of the preferred and prostrate (face-down) postures of the 95th percentile drivers.

	Length	Width
Preferred Position	78 in	33 in
Prostrate position	80 in	34 in
Legal Specification	75 in	24 in

Design of Work Surfaces:

- Work surfaces

– Within the envelope of a workplace, specific design decisions need to be made about various features of the workplace e.g. the location and design of work surfaces

  - e.g. surface involved benches, desks, tables, etc.

Design of the work surfaces:

– Horizontal work surface area

– Work surface height: seated

– Work surface height: standing

Design: Horizontal work surfaces

- **Horizontal work surface area**

– To be used by seated and "sit stand" should provide for manual activities to be within convenient arm's reach.

- **Work surface area definition and dimensions**

– Normal area and maximum area (Barnes, 1963)

- Normal area:

– The area can be conveniently reached with a sweep of the forearm while the upper arm hangs in a natural position at the side.

- Maximum area:

– The area could be reached by extending the arm from the shoulder.

- According to Squires (1956): Work surface area with the dynamic interaction of the movement of the forearm as the elbow is moving (Squires,1956).

Working Area (NWA or MWA)

- **Normal working are (NWA)**

– NWA allows hand motion to be made in a convenient zone with normal energy expenditure.

– Area described by the arms and hands with the elbows flexed at ~90 degree.

- **Maximum working area(MWA)**

– MWA is the intersection of the ZCR with the horizontal surface such as table or bench.

Squires Model

-Less forward action of the forearm.

- Minimize stress on the elbow joint

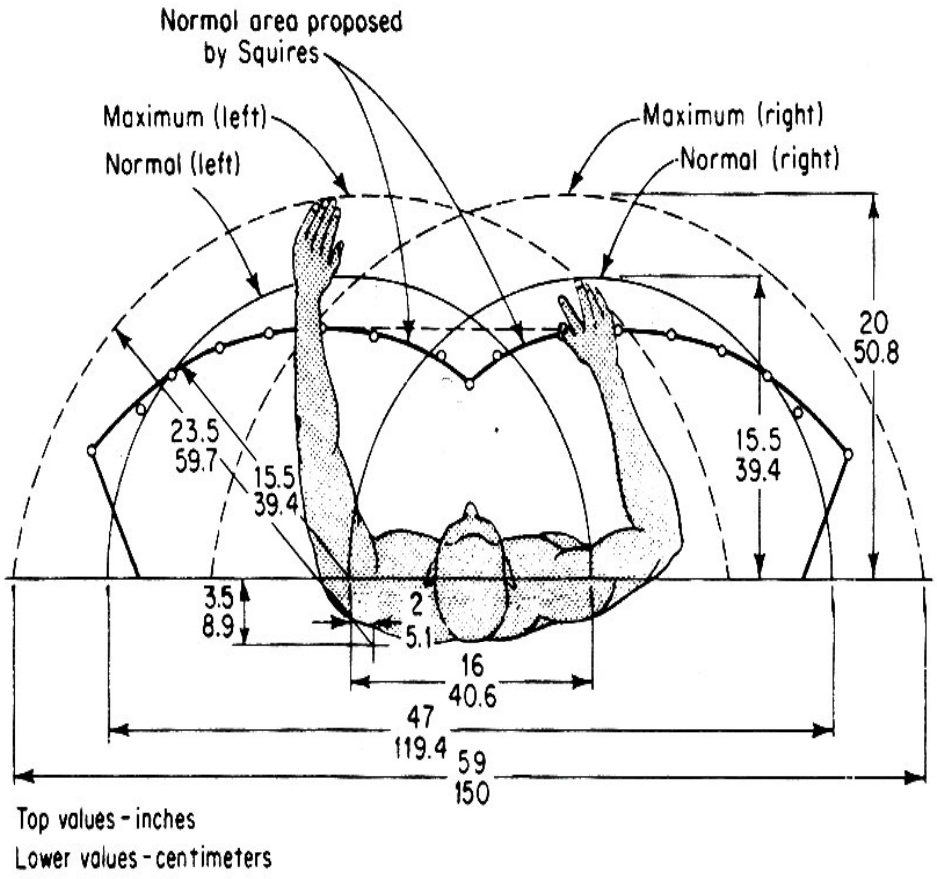


그림 13-11 Barnes가 제안한 수평면에서의 표준 및 최대 작업영역 치수(in 및 cm). S
제안한 표준 작업영역을 중첩시켜서 차이를 보였다.

(Barnes, 1963; Squires, 1956)

- **Slanted surfaces for visual tasks:**

Eastman and Kamon, (1976)

-They found that subjects using slanted surfaces (12°and 24°)had better posture

- Less trunk movement, less fatigue, and less discomfort than when using horizontal surfaces.

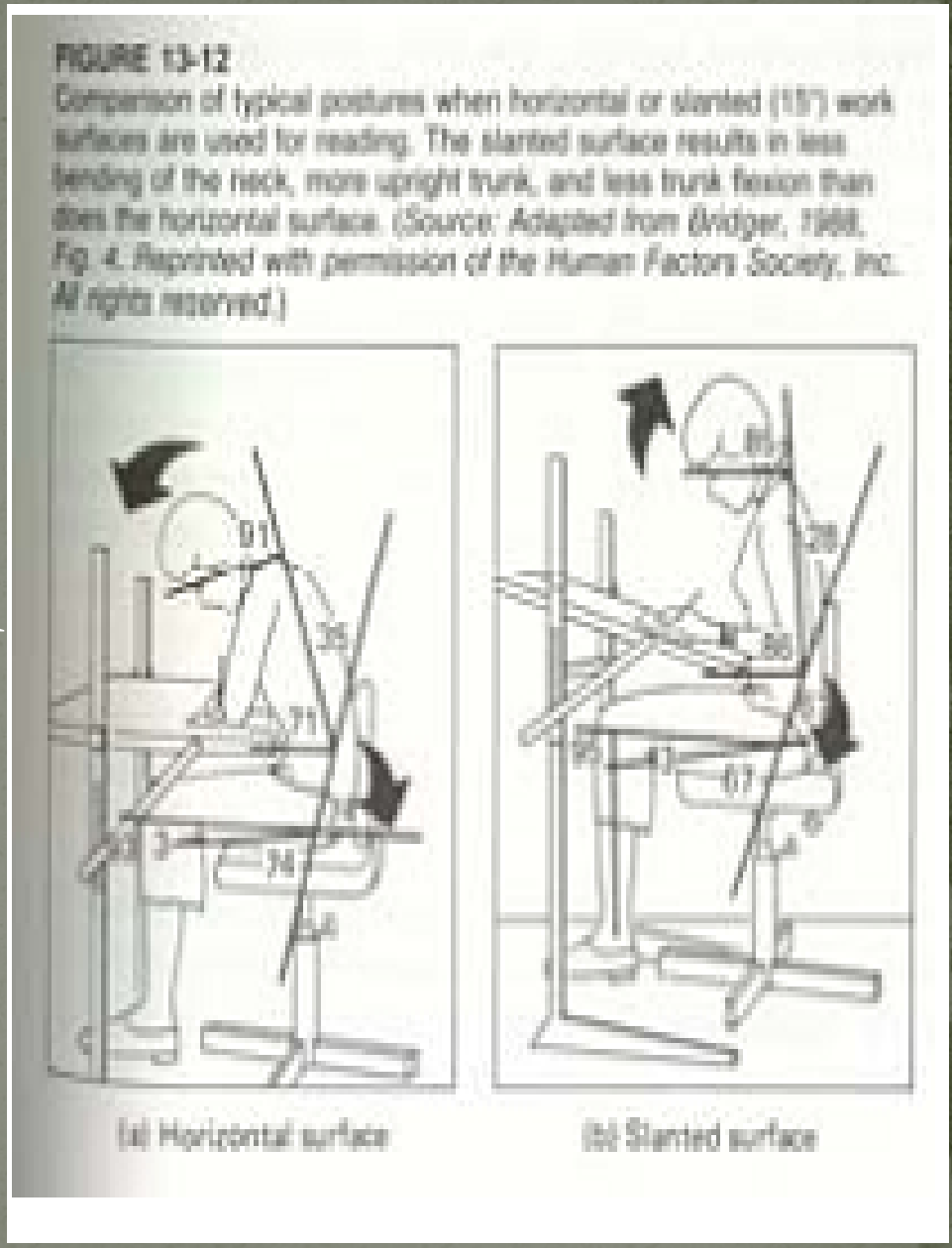
Bridger (1988)

Slanted surfaces 15 °

Less bending of the neck

More upright trunk

Less trunk flexion



Work Surface Height Seated

- Work surface height:
  - The height of the upper surface of a table, bench, desk, counter, measured from the floor.
- Working height:
  - Depends on what one is working on.
- When writing on paper: the working height =the work surface height.
- When using a keyboard: above the work surface height
- When washing vegetables in a sink: below the work surface height.

Seated work-surface height and arm posture

- Reducing work surface heights to permit relaxed postures of the upper arms with respect to working height.
- The heights of desks have been reduced from about 30 in to about 28.5” in 1970 in Europe but, further reduction of the heights to about 27”. (Bex,1971).

. Upper arm and elbows at 90 degree provides comfort and helps to maintain a straight wrist.

- Seated work-surface height and thigh clearance

•W/S height is also Influenced by

-seat height,

-the thickness of the work surface, and

-the thickness of the thighs.

- The clearance between the seat and the underside of the work surface should accommodate the thighs of the largest user.
  - 26.2" as the minimum height for the underside of a nonadjustable seated work surface (ANSI, 1988).
    - Problems for smaller people (e.g. raising chair, foot rest.)

Solution: A range of height adjustments 20.2"to 26.2" (ANSI,1988).

General principles for seated work surfaces

- The work-surface height should be adjustable to fit individual physical dimensions and preferences.
- The work surface should be at a level that places the working height at elbow height.
- The work surface should provide adequate clearance for a person's thighs under the work surface.

Seated Work Surface height and the Nature of the task:

Working surface should be 6 and 2 inch above elbow height respectively for fine and precision work. // conflicting with the 2nd principle

TABLE 13-2
RECOMMENDATIONS FOR SEATED WORK-SURFACE HEIGHTS FOR VARIOUS TYPES OF TASKS

	Male		Female	
Type of task (seated)	in	cm	in	cm
Fine work (e.g., fine assembly)[1]	39.0–41.5	99–105	35.0–37.5	89–95
Precision work (e.g., mechanical assembly)[1]	35.0–37.0	89–94	32.5–34.5	82–87
Light assembly[1]	29.0–31.0	74–78	27.5–29.5	70–75
Coarse or medium work[1]	27.0–28.5	69–72	26.0–27.5	66–70
Reading and writing[2]	29.0–31.0	74–78	27.5–29.0	70–74
Range for typing desks[2]	23.5–27.5	60–70	23.5–27.5	60–70
Computer keyboard use[3]	23.0–28.0	58–71	23.0–28.0	58–71

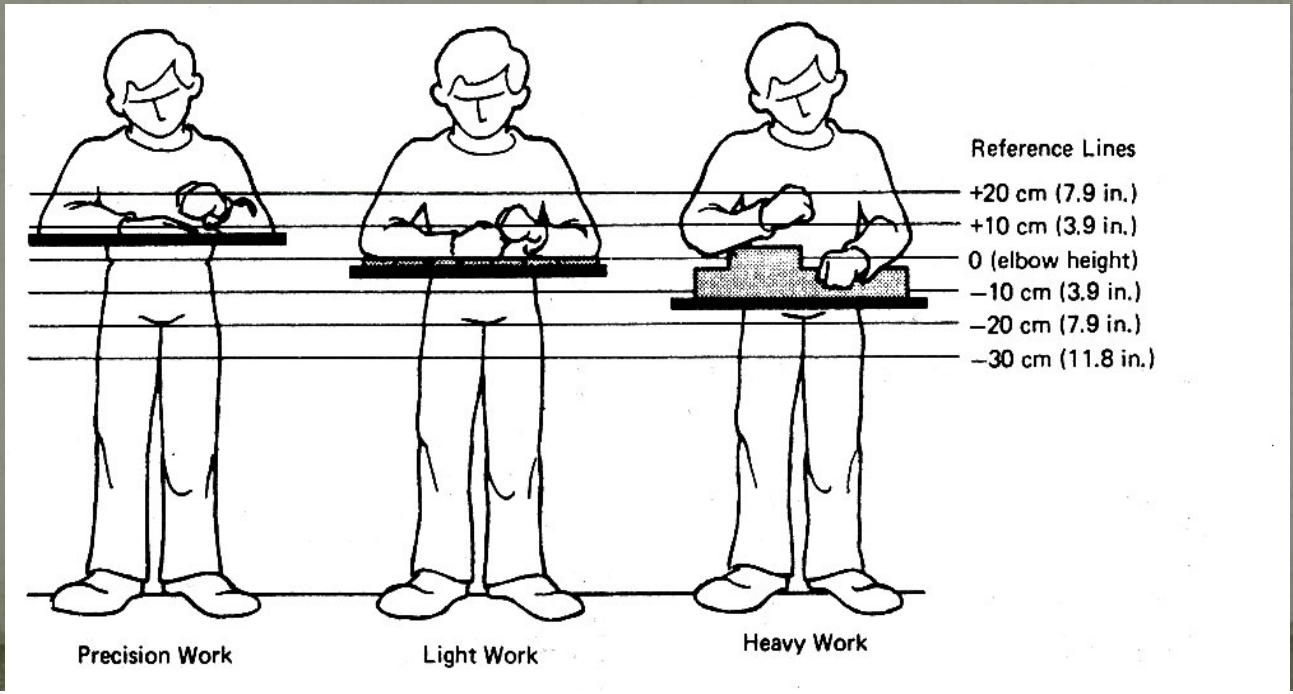
Sources: [1] Ayoub, 1973; [2] Grandjean, 1988; [3] Human Factors Society, 1988.

Work Surface height : Standing

1. **The surface height is related to the nature of task and elbow height.**

– Heights for precision work, light work, and heavy work as related to elbow height (Grandjean, 1988)

- For light and heavy work are below elbow height
- For precision work is slightly above elbow height.



2. The surface height is also related to the individual preferences (Word & Kirk, 1970).

TABLE 13-3
PERCENTAGE OF SUBJECTS EXPRESSING PREFERRED WORK-SURFACE HEIGHTS IN PERFORMING THREE KITCHEN TASKS

Type of task	Level relative to elbow		
	Lower	Even	Above
Working above surface (peeling vegetables, slicing bread, etc.)	54	14	32
Working on surface (spreading butter, chopping ingredients, etc.)	16	11	73
Exerting pressure (ironing, rolling pastry, etc.)	41	9	50

Source: Ward and Kirk, 1970.

Recommended Standing work surface heights for 3 types of work

Type	Gender	Fixed Height(in)	Adjustable Height(in)
Precision work	Male Female	49.5 45.5	42-49.5 37-45.5
Light Assembly work	Male Female	42 38	34.5-42 32-38
Heavy Work	Male Female	39 35	31.5-39 29-35

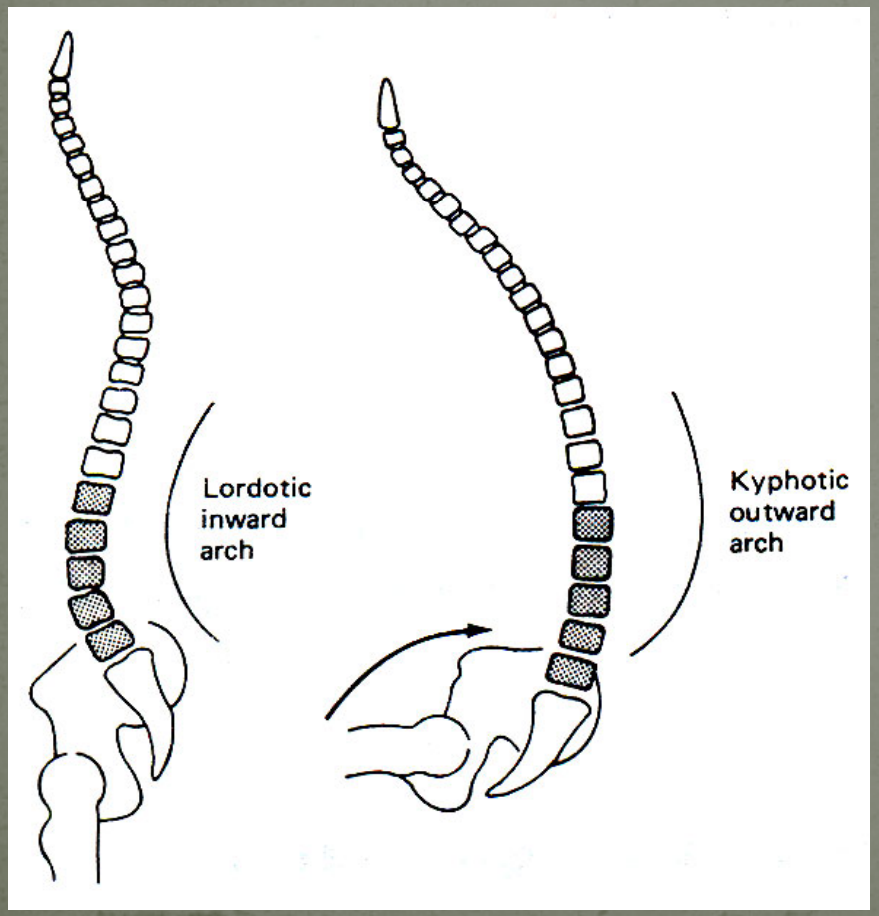
Work Sufaces for Standing or Sitting

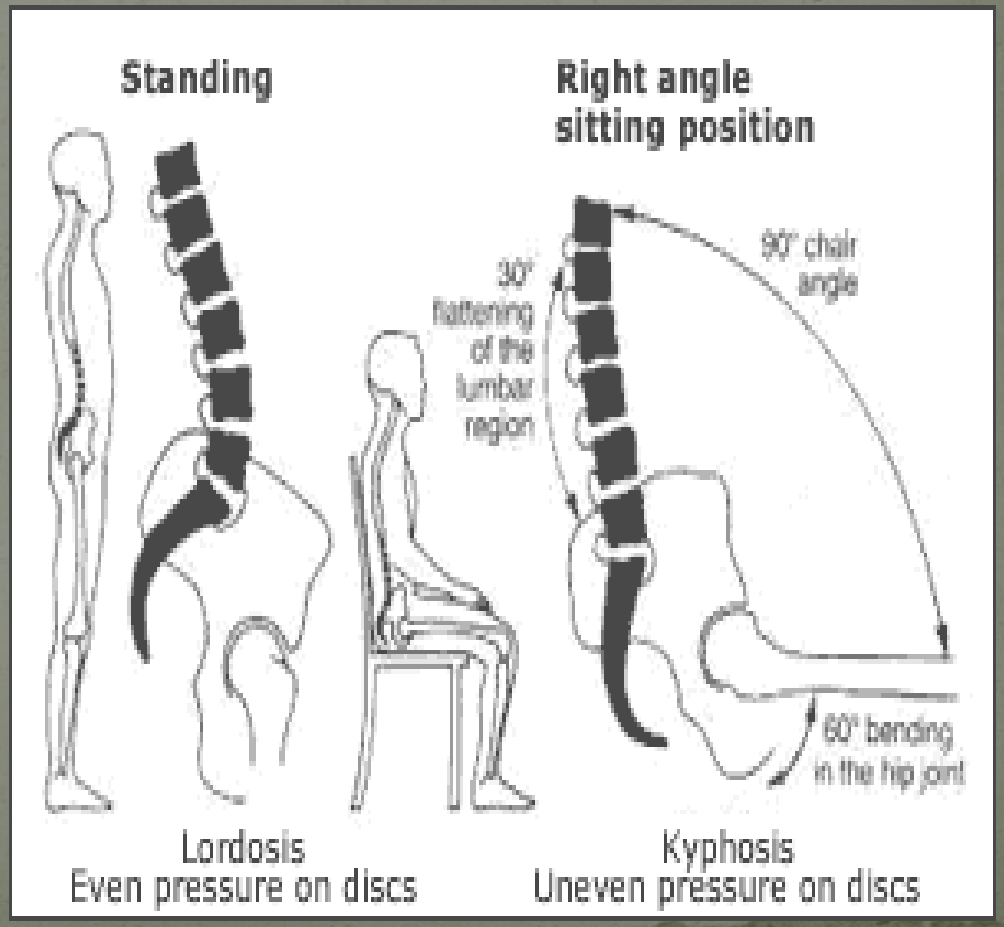
- Upper Arm Rest
- Footrest

General Principles of Seat Design

1. Promote Lumbar Lordosis:

Lordotic: Standing Erect – curved inward (concave)
Kyphotic: Sitting with thighs at 90 degree(convex)
Kyphotic Occurs because: hip joint moves 60 degree
Forces Pelvis to move backward 30 deg





Problem: Increased Pressure in Discs located between the vertebrae of the spine

Solutions:

i. 2 in thick lumbar support with a seat backrest angle 90 deg.
- with back rest angle 110 degree and lumber support- the lumber spine was almost in the curve of a person standing.(Andersson et al. 1979)

ii. Forward tilting seat:

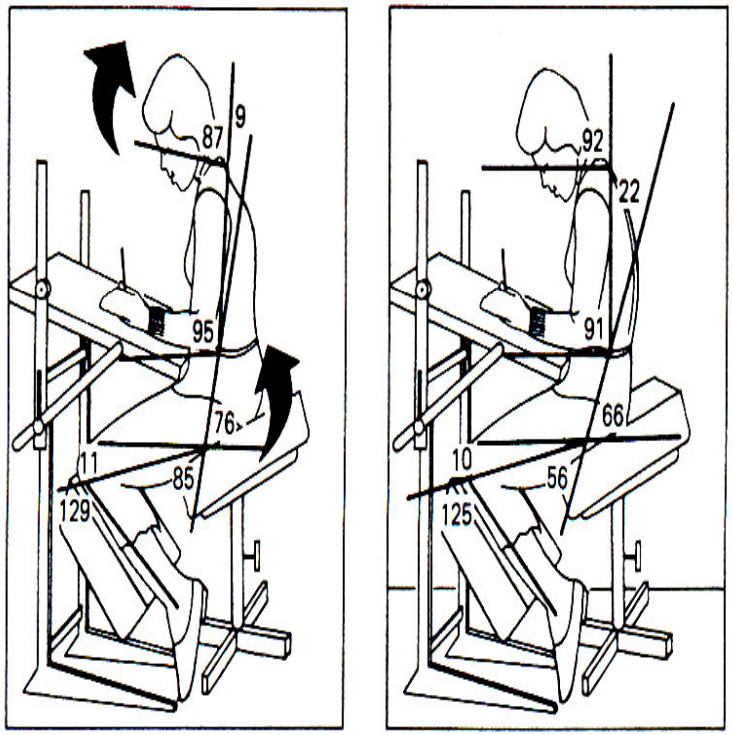
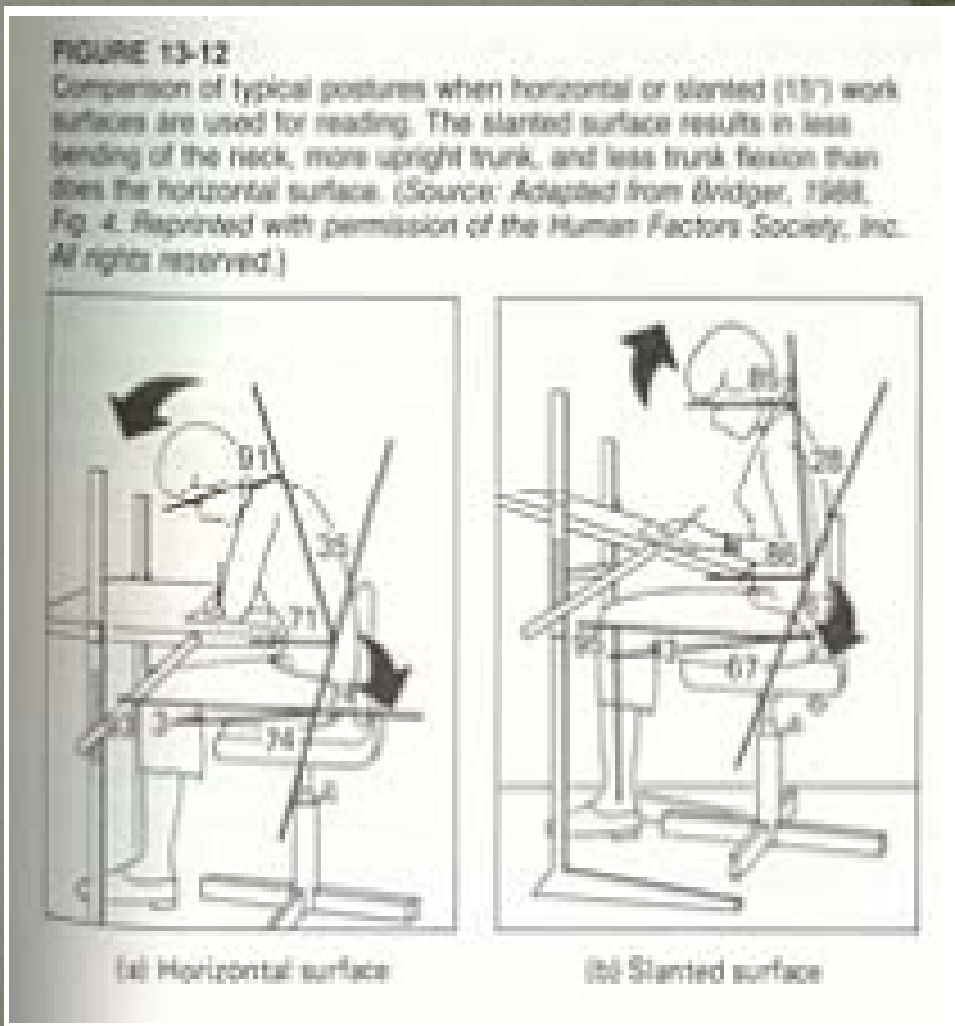


그림 13-16 경사 작업면을 사용할 때 앞으로 기운 좌석에 앉은 사람에게서 관찰한 두 가지 공통 자세: (a) 곧은 자세와 (b) 굽은 자세.

(Bridger, 1988, Figs. 4d and 5)



2. Minimize Disc pressure

- Lumbar disc pressure varies with back posture and the load in the hands (Nachemson, 1974).
  - Unsupported sitting in an upright, erect posture (forced lordosis): resulted in a 40 % increase in pressure compared to standing (Nachemson& Elfstrom, 1970). (,)
  - Unsupported sitting in a forward slumped posture: increased pressure 90% compared to standing (Nachemson& Elfstrom, 1970).

SOLUTION:

-Use of a reclined backrest has an effect with reductions in pressure by reclining backrests from vertical (90°) to 100 to 110 ° .

- Use of a lumber support reduces disc pressure as does
- the use of arm rests. (Anderson, 1987)

3.Minimize Static Loading of the Back Muscles:

- Back muscle pain – Backrest angle and muscle activity:
  – Muscular activity as measured by electromyography

(EMG) is similar when standing or witting. EMG activity decreases when sitting in a forward slumped posture, even though maximum pressure on the discs (Anderson, 1987).

– A reduction in muscular activity in the back when the backrest was reclines up to 110 degree (Anderson, 1987).

4. Reduce postural fixity

– postural fixity :sitting in one position for long periods without postural movement (Grieco, 1986).

Problems: -postural fixity promotes static loading of the back and shoulder muscles,

-restriction in blood flow to the legs,

-discomfort.

Solution: i. Chair design can reduce postural fixity some by allowing the user to rock in the chair and assume a variety of postures.

ii. Periodically stand up.

iii. Leave a note.

5. Provide for easy adjustibility

– Providing adjustable seats increases productivity (Springer, 1982).

– Reduces complaints of shoulder and back pain (Shute and Starr, 1984).

– People are not aware of the adjustability features and rarely use.

• About 10% adjusted their seats during the day (Kleeman & Prunier,1980).

– Guidelines for increasing the use (Lueder, 1986):

- Controls can be easily reached and adjusted
- Instructions on the furniture are easy to understand
- Controls are easy to find and interpret
- Tools are not necessary.
- Controls provide immediate feedback
- The direction of operation of controls is logical and consistent
- Few motions are required.
- Adjustments require the use of only one hand.

Specific Design Recommendation

- Ergonomic chair recommendations

• **Seat height and slope**

Fixed Height: 18 to 19 inch

Adjustable Height: Minimum range of 16 to 20.5 in based on a compressed seat (ANSI)

– 5 to 15 °forward tilt to 5 °backward tilt (Lueder,1986)

• Seat depth and width

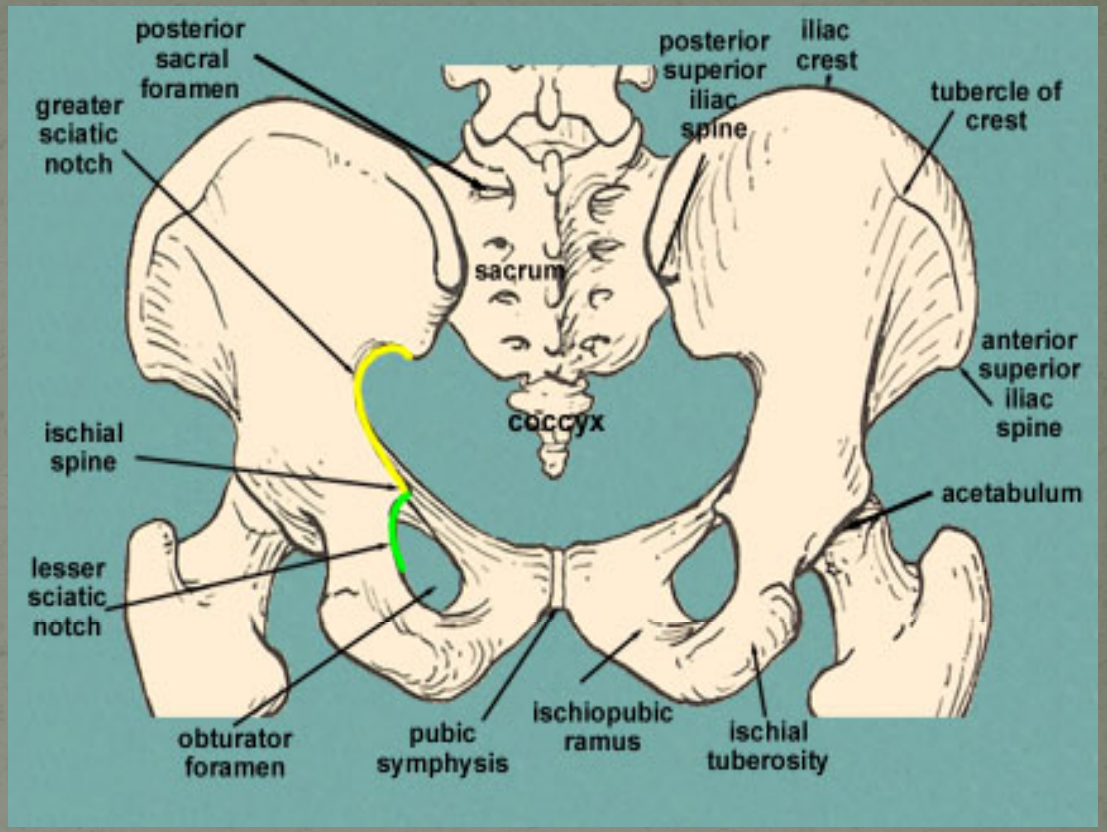
– Chairs depth Should not exceed 16.8” and the width of the seat surface be not less than 15.7” (Grandjean et al, 1973).

– Seat depth: 15 to 17 in (ANSI) Seat width: 18 2 in (ANSI)

· Contouring and cushioning

Contouring:

Disadvantages:
i. Restricting Movement
ii. Promoting postural fixity



Cushioning:
Disadvantages of Soft cushion:
i. Posture is Restricted ii. Blood Circulation is Reduced iii. Skin Temperature increase iv. Pain May results.
SOLUTIONS
– Seat cushion thickness range from 1.5 to 2" (Lueder, 1986).

• **Seat back parameters**

– Seat back angle: a minimum range of 90°to 105 °with the seat pan.

- up to 120° (ANSI)

– Seat back width: at least 12” in the lumbar region.

– Seat back height: a minimum of 19.5” (Lueder, 1986).

-Lumber Support:

Height: 6-9 in

Width: 12 in

Position: 6-10 in above SRP

Protrude: 2 in from the back of the seat

Seat Design for Specific Purposes:

Combination of Art and Science

Computer Workstation Chair

Dynamic Seat Design(Lueder 1991)

1. Designs in which the seat motions are synchronized automatically.
2. Floating Backrest.
3. New flexible seat material

Cyborg Chair

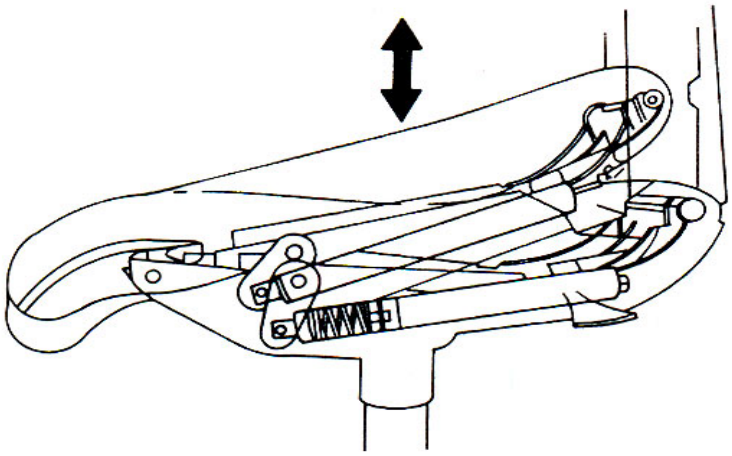


그림 13-18 Cyborg 의자의 좌석판 종단면.
앉아있는 동안에 체중의 변화에 따라 좌석판 각도의 동적 변화 메커니즘과 범위를 보였다. 제작자의 주장에 따르면 좌석판 각도의 변화에 따라 사용자가 자세를 바꿀 수 밖에 없으므로 자세고정을 감소시킨다.
(Rudd International, Inc., Washington, DC.)

Multi Purpose Chairs:

Study: on 25 men and 25 women
Rated: comfort on 11 parts of body
Number of chairs: 12

Recommendations:

1. 2 different most comfortable contours
2. Foam rubber of 2-4 cm on the entire seat.

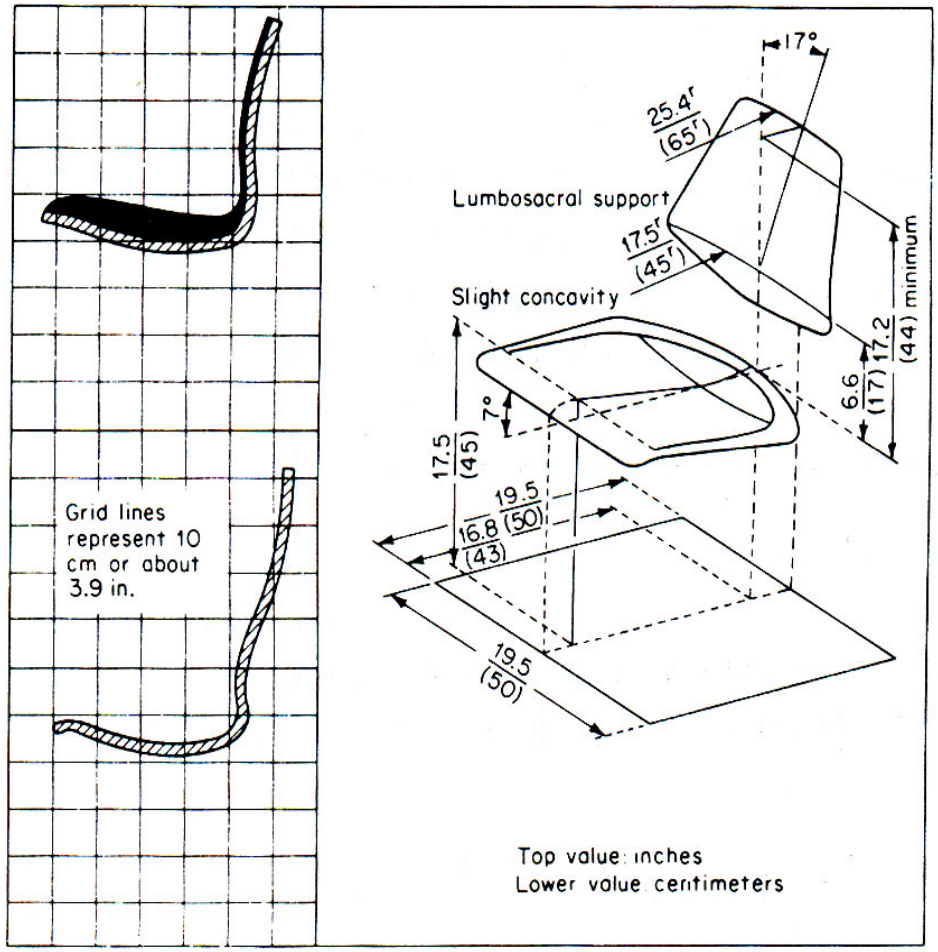


그림 13-19 50명의 피검자가 12 가지 의자 중에서 가장 편안하다고 판단한 두 가지 다목적 의자의 콘투어와 연구에 기초한 다목적 의자에 대하여 권장한 설계 특징

(Grandjean et al., 1973, Figs. 2, 6, 13)

Reading and Resting

Grandjean, Boni and Krestzschmer studied:

Dimension	Reading	Resting
Seat Inclination , deg	23-24	25-26
Backrest inclination, deg	101-104	105-108
Seat height	30-40 cm	37-38 cm

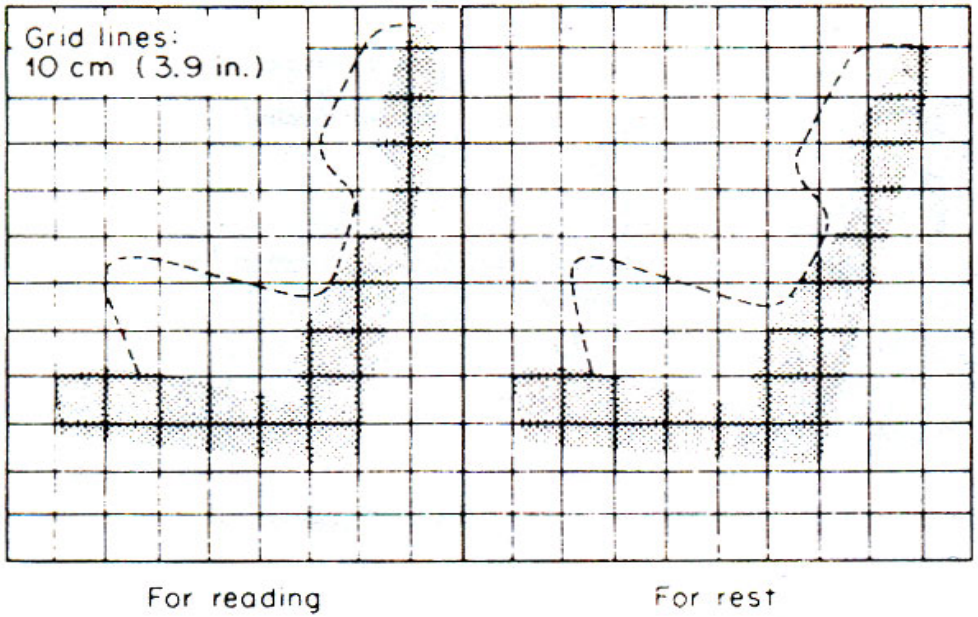
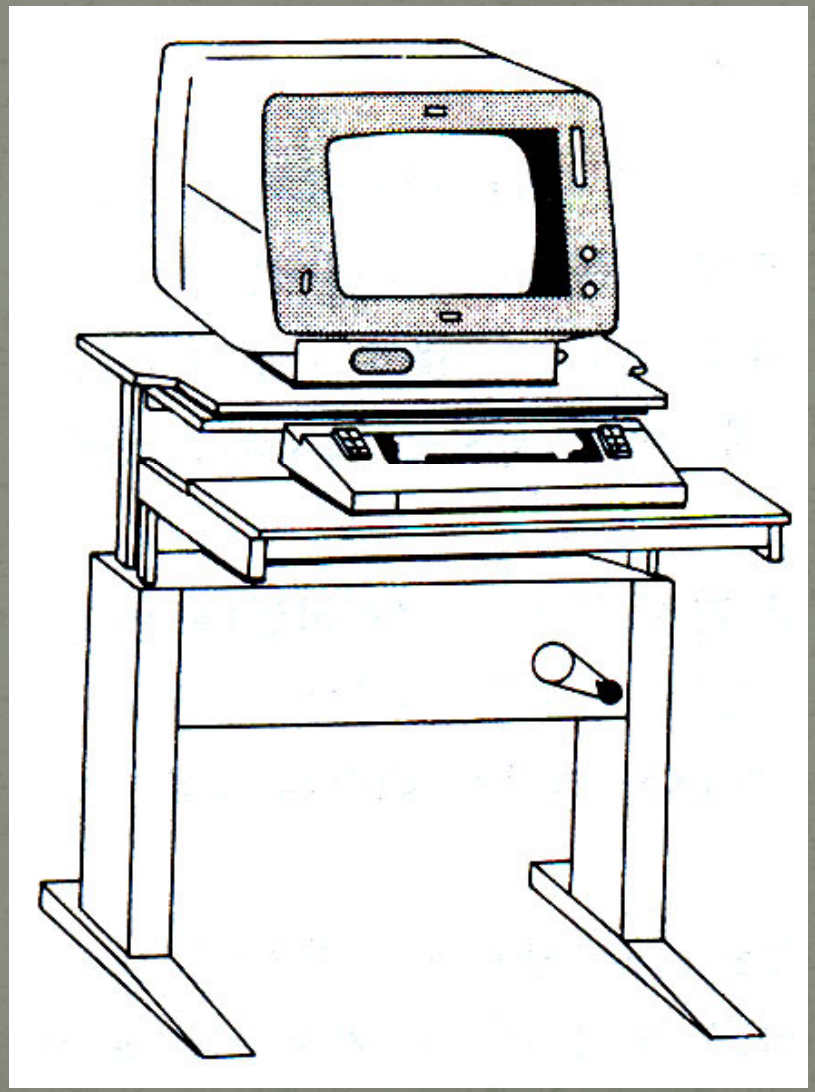


그림 13-20 독서용 및 휴식용 의자의 프로필.
점선은 팔받이 및 가능한 콘두어에 해당하며, 어두운 부문은 6 cm(2.5 in) 두께의 덮개를 포함한 좌석 표면을 보인 것이다.
(Grandjean, Boni, and Krestzschmer, 1969, Fig.2, p.310)

Video Display Terminal(VDT) workstations:



Dressel and Francis (1987)

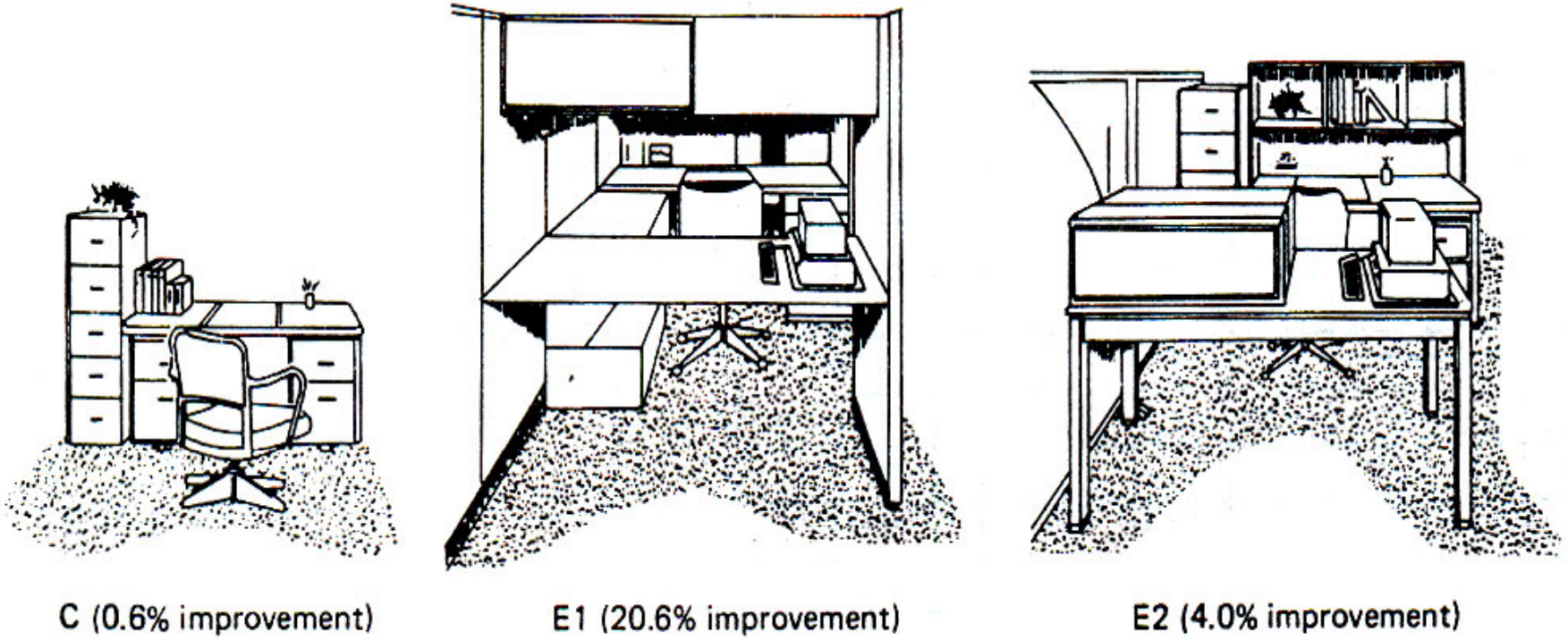


그림 13-22 Dressel과 Francis가 평가한 세 가지 작업대

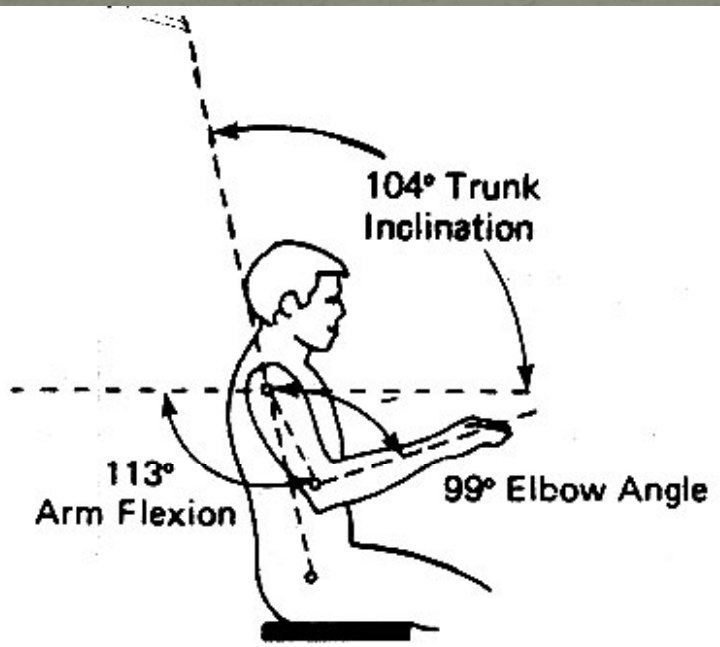
대조(C) 작업대는 관급(官給) 철제가구이다. E1 작업대는 전혀 새로운 집기로서 "에르고노믹" 의자가 포함되었다. E2 작업대는 C 작업대에 철제 집기를 추가한 것이다. 결과는 생산성의 전후 변화를 비교한 것이다. (Dressel and Francis, 1987, Fig.1)

The Use of Guideline and Standards:

Shortcomings of guidelines :Daindoff and Daindoff (1986)

1. There are major differences in coverage, structure, and degree of details between the various sources.
2. The problem of obsolescence.
3. The specific contents of many standards and guidelines simply are not in agreement and the extent of disagreement can be quite large.
4. Researches are based on only one factor.

User Preferences:

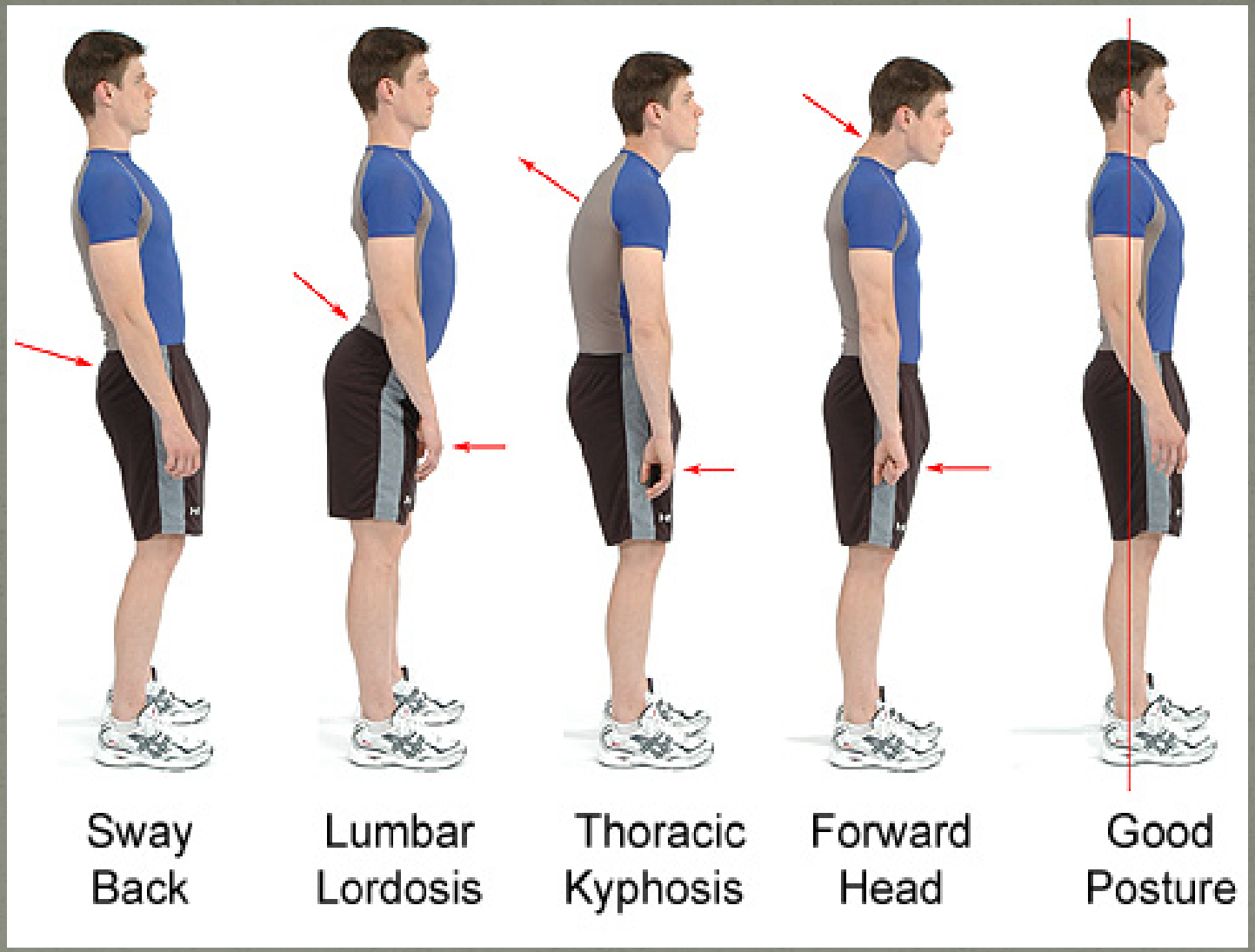


(a)

(b)

그림 13-23 전형적 VDT 사용자 자세

(a) VDT 사용자가 취하는 관련 신체 각도(평균치)
(b) 전형적 자세의 스케치 - 의자에 등을 기댄다.
(Geandjena, 1987, Figs.83 and 85)


Sway Back
Lumbar Lordosis
Thoracic Kyphosis
Forward Head
Good Posture