

# ENGINEERING APPROACHES TO STANDING, SITTING, AND LYING

Akhtar Rasul

# *Biomechanics of Standing*

- Muscles extending from the neck to the ankle= prevention of buckling
- Types of skeletal muscle fibers
- Postural Muscles
- Mixed composition of muscles
- Force proportion of postural to phasic muscles is 3:2
- High-level sports or athletic training, can change this proportion to even 5: 1

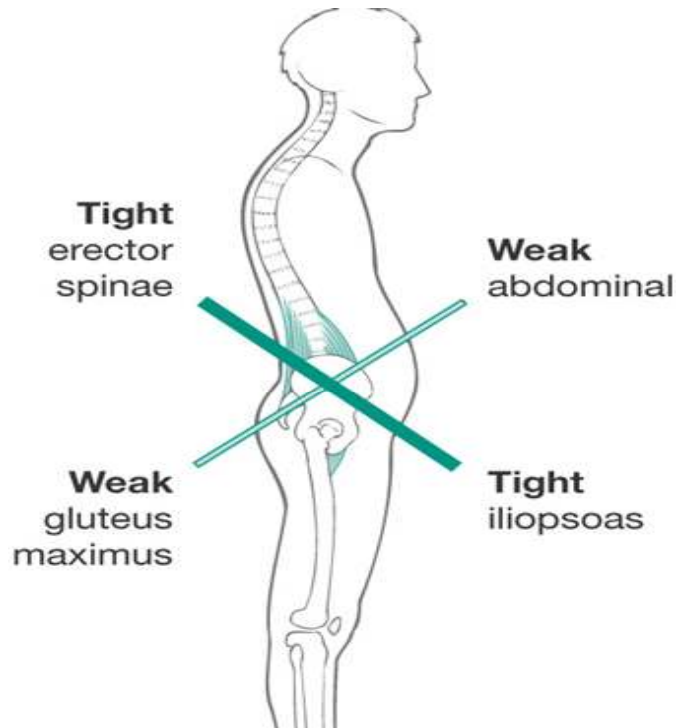
# Relationship between postural and phasic muscles

- Postural muscles tend to spontaneous functional or even anatomical shortening → a higher muscle tonus.
- Postural muscles have an inhibiting effect on their phasic partners
- With insufficient variety in muscle use → which leads to inhibition and weakening of phasic muscles (pseudo paresis) → imbalance, postural dysfunction, deformities etc

# Distal crossed syndrome



- Shortened back extensor and hip flexor muscles
- Weakened abdominal and buttock muscles.
- Anterior pelvic tilt and hyper- Lordosis are the result, which also manifests in walking with insufficient hip extension (normal is 5 to 10 degree).




**Distal crossed syndrome**

# Proximal Crossed syndrome

---

- Shortened Pectoralis major, cervical Trapezius, Levator scapulae, and, less pronounced, the Sternocleidomastoid muscles
- weakened fixator muscles of the scapulae (rhomboids, distal and middle parts of the Trapezius, and the serratus anterior muscles) and the deep flexor muscles of neck

- 
- Postural deterioration with the head placed forward, the shoulder blades raised and abducted, the upper part of the cervical spine overextended, and the shoulders moved forward.

Tight Upper  
Trapezius  
& Levator  
Scapula

Inhibited  
Rhomboids  
& Serratus  
Anterior

Tight Erector  
Spinae

Inhibited  
Gluteals



Inhibited Neck  
Flexors


Tight  
Pectorals


Inhibited  
Abdominals


Tight  
Iliopsoas


**Figure 5.V. Janda's upper and lower crossed syndromes.**  
*MediClip, Lippincott, Williams & Wilkins, 2005 with permission.*



- 
- Aid of force plate
  - Centre of pressure
  - Swaying
  - Consumption of alcohol and other medications
  - Static and dynamic determination

- 
- **Look at the inclination of the foot**, not at the height of the heel, because the inclination determines the degree to which a person loads the forefoot.
  - Excessive instability or play is characteristic of an unstable joint, as compared with that of the healthy joint
  - Instability refers to a Susceptibility to tilting or falling as a result of interfering forces.

- 
- In the **top view** of the foot one can identify **three points** where great forces are possible.
  - Both in the **lateral and frontal view** of the foot, **two points** of support are found at a distance from one another.
  - In the **posterior view**, however, only **one point** of support at the heel exists. In this unstable situation, the heel must get stability from the ball if the ankle fails
  - A stable positioning of the foot in a shoe means little if the shoe itself is unstable in relation to the ground because of a stiletto heel or a curved sole.

- 
- Arch of the foot
  - Weight bearing
  - Planter Aponeurosis
  - Stooped postures often occur because of the role of the eyes in combination with the work of the hands.

- 
- Comparison of stoop posture with the normal standing
  - Which one is advantageous?

# Reaching




- Person reaches as far as possible to a distant object while the feet cannot be placed any further forward
- Because of the design of the machine involved or because the toes touch a tank with liquid
- Provision of a support for the pelvis

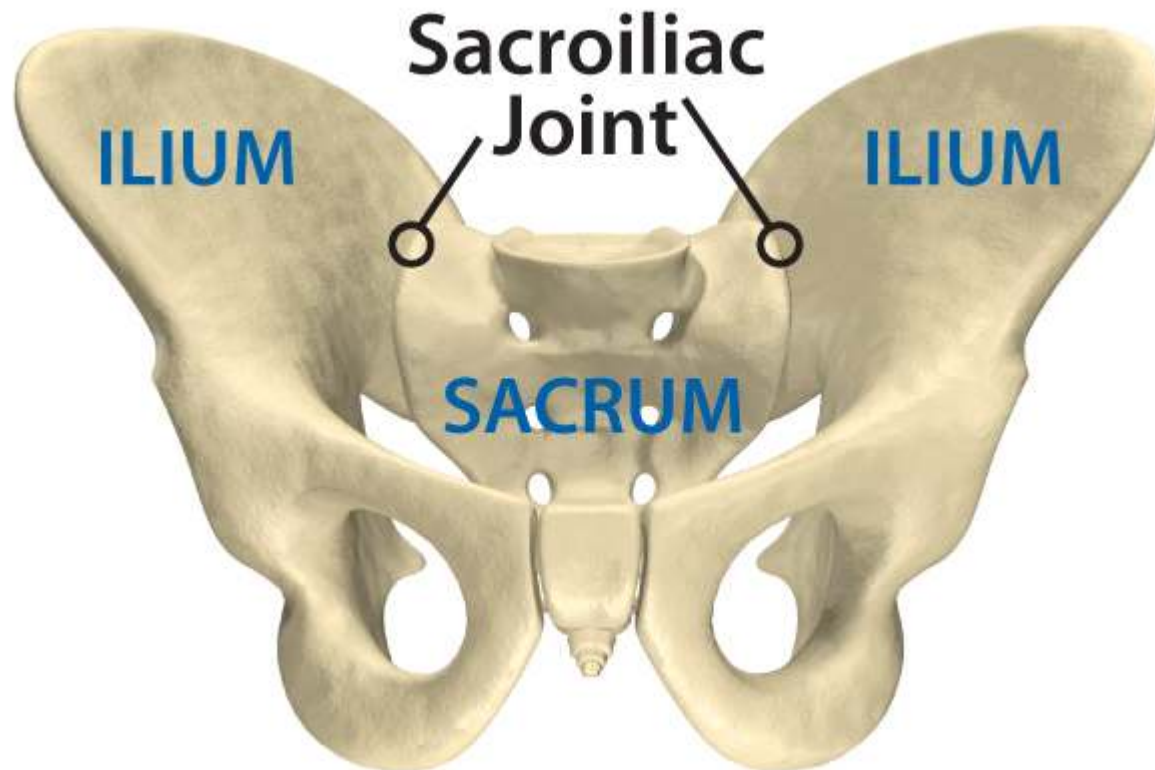
# Biomechanics Of The Pelvis

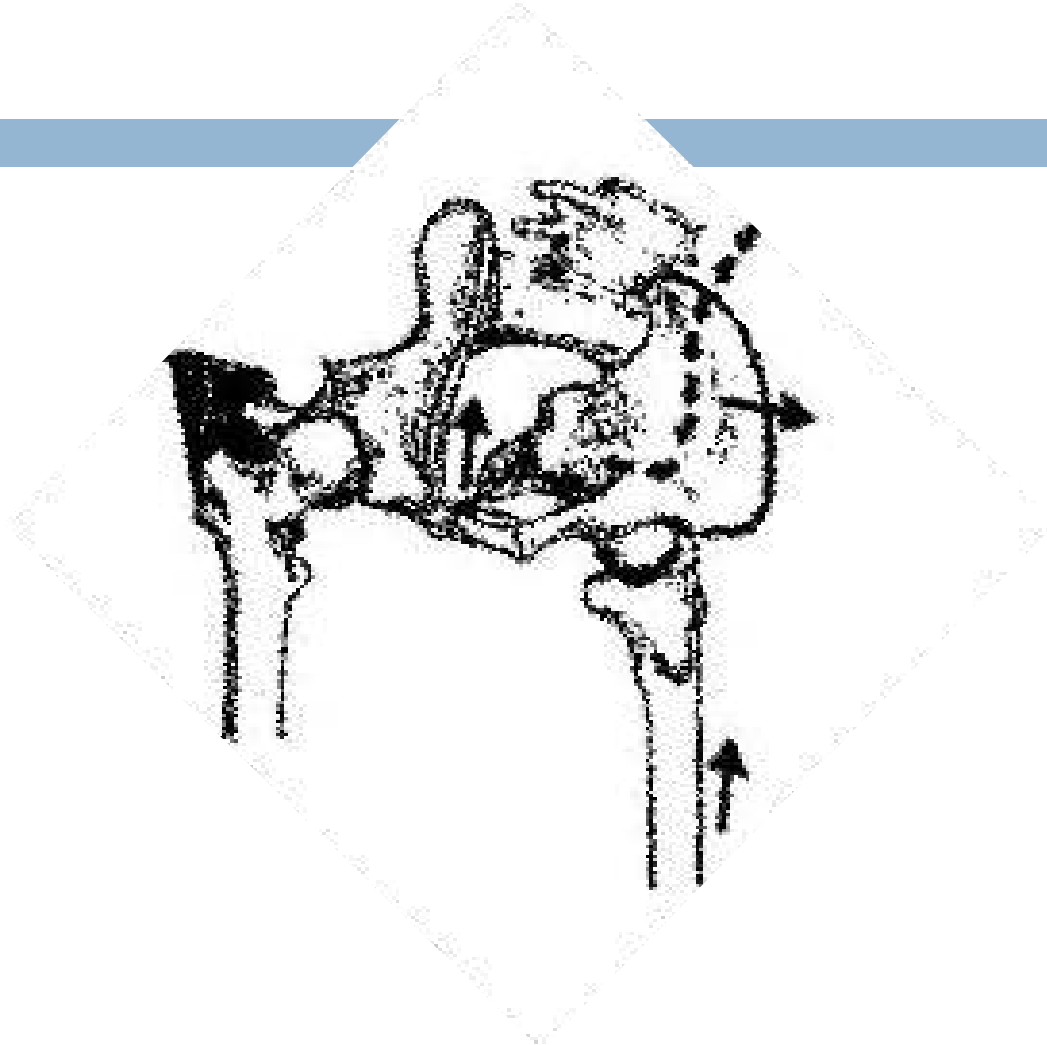


- Largest forces always act in the longitudinal direction of the spine
- Position of the Intervertebral discs  
→ Perpendicular to the longitudinal orientation of the spine

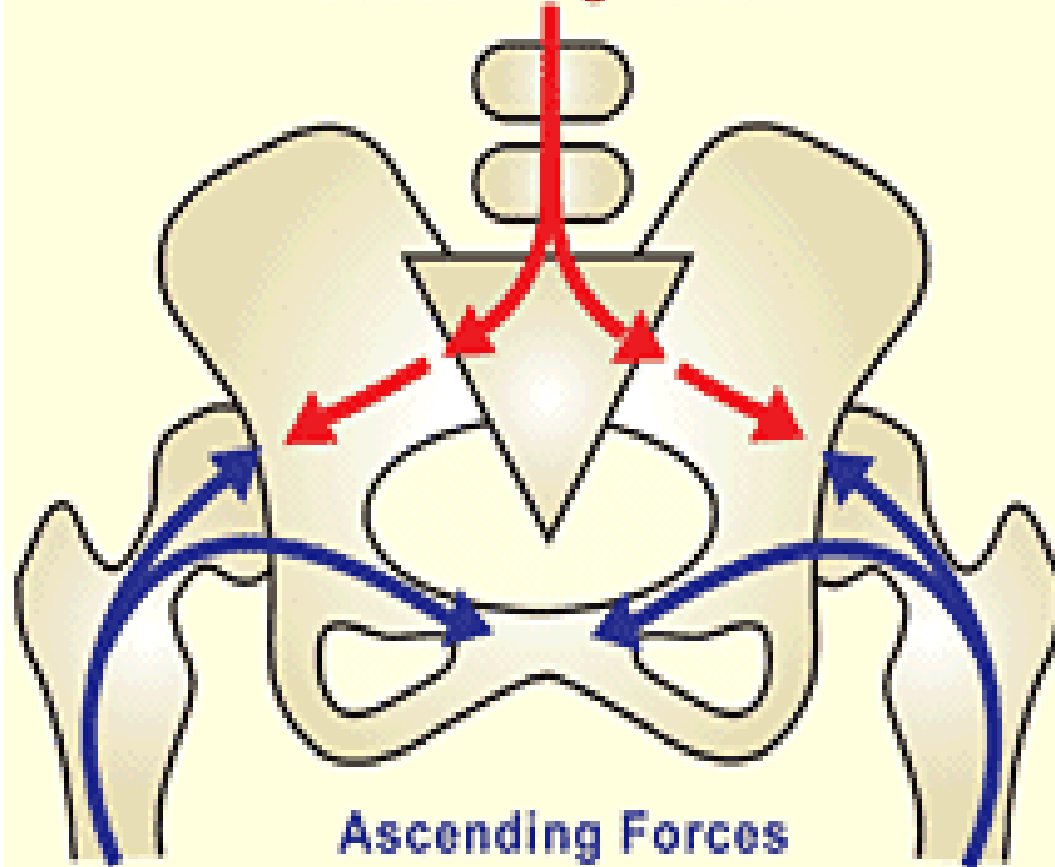
- 
- **Sacroiliac joint** surfaces are **parallel** to the largest forces and are not protected against dislocation by the closed form of a ball and socket joint.
  - SI joints are vulnerable to **shearing** because of their predominant flat surfaces. which are almost parallel to the plane of maximal load








**Descending Forces**



**Ascending Forces**

- 
- Strong ligamentous support & Muscle forces → compression of joint surface → prevention of shear loading
  - self bracing

# Flat Versus Ball and Socket Joint

- Forces near and in the plane of a **flat joint** result in shearing before this movement is stopped by ligaments.
- Ball and socket joint is well protected against shear.
- Because of the greater lever arm, a pure bending moment can be better transferred by a flat joint than by a ball and socket joint

# Sitting



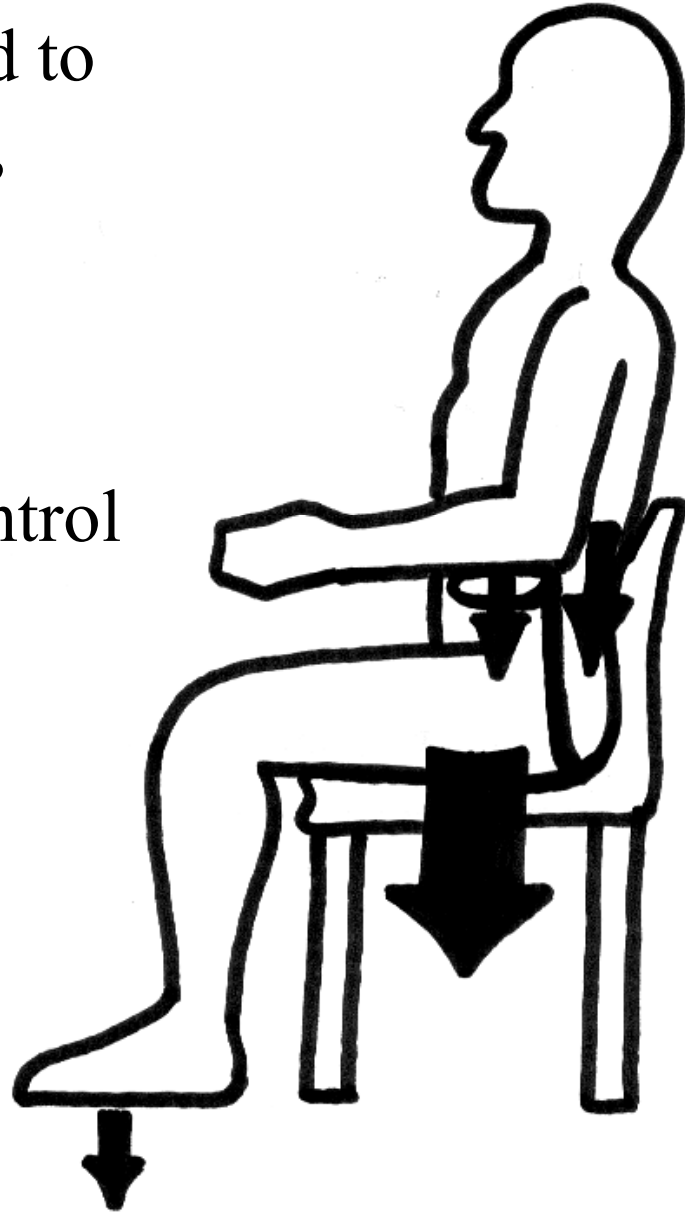
- Evaluation of design criteria on the basis of biomechanical aspects
- A good sitting posture is characterized by minimal muscle effort, which is produced with proper support by arm rests, back rest, seat, and foot rest.
- Ability to change posture regularly

## Weight Transfer

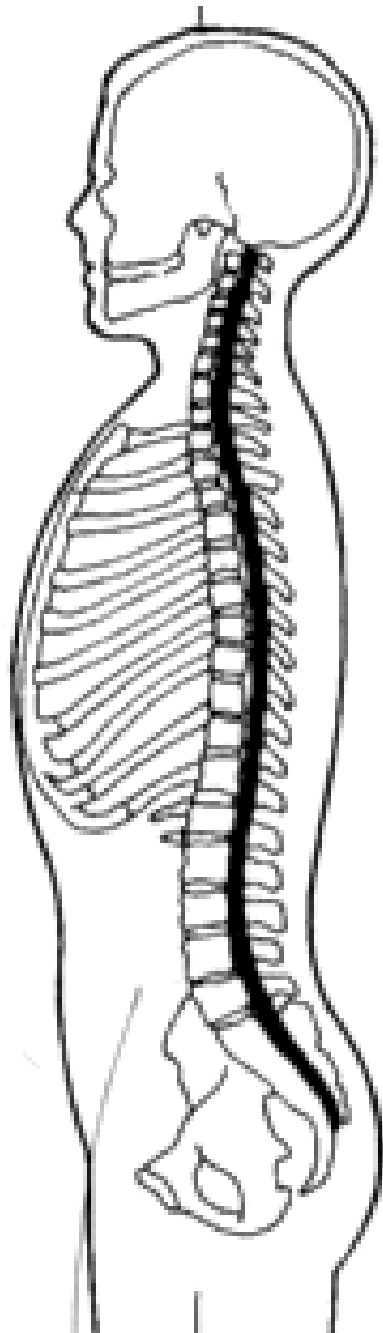
- Main body weight transferred to seat. Some transferred to floor, backrest, and armrests.

## Advantages

- Provides stability to tasks involving visual and motor control
- Less energy consuming than standing
- Places less stress on lower extremity joints
- Lessens pressure on lower extremity circulation



[Hall, 1999]

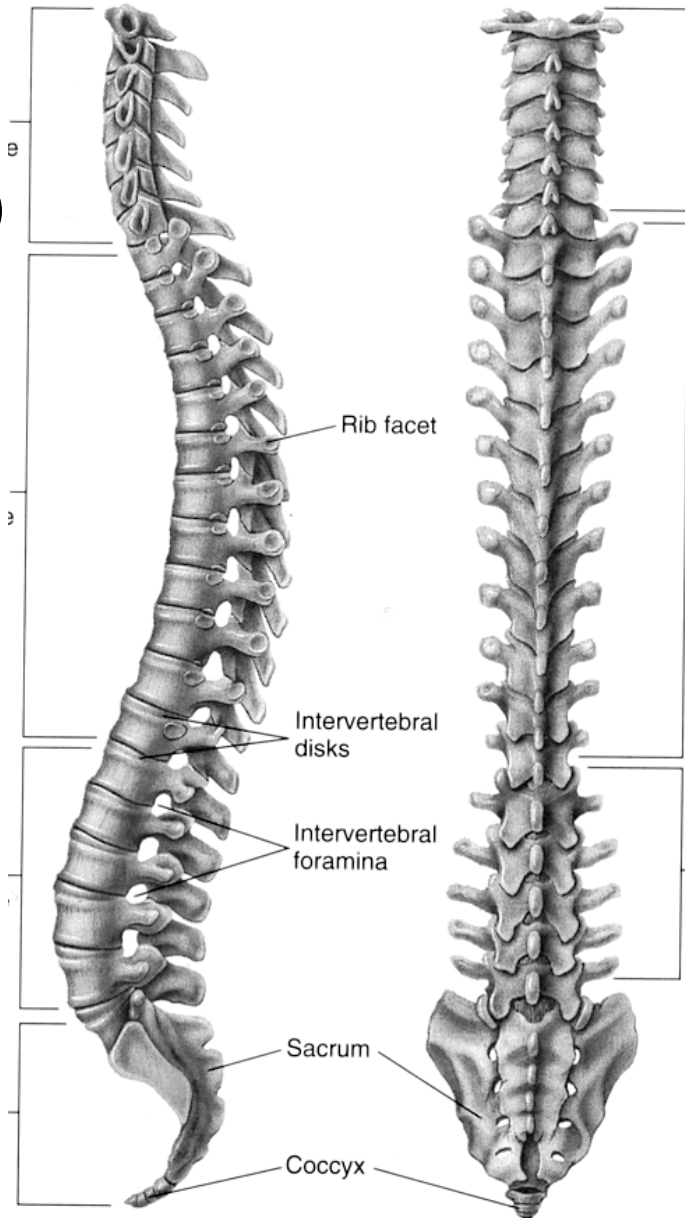


**Cervical**  
Vertebrae  
(C1 to C7)

**Thoracic**  
Vertebrae  
(T1 to T12)

**Lumbar**  
Vertebrae  
(L1 to L5)

**Sacrum**  
(S1 to S5)

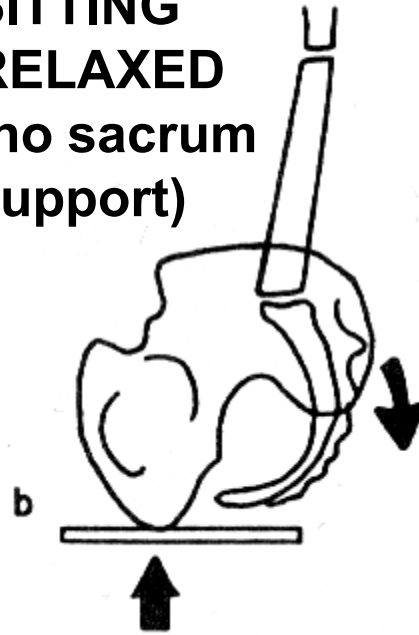




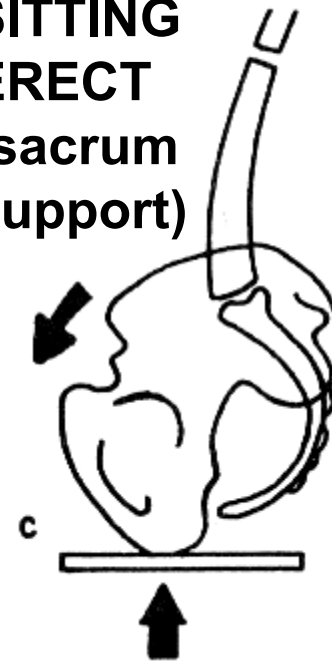
**STANDING**



**SITTING  
RELAXED  
(no sacrum  
support)**



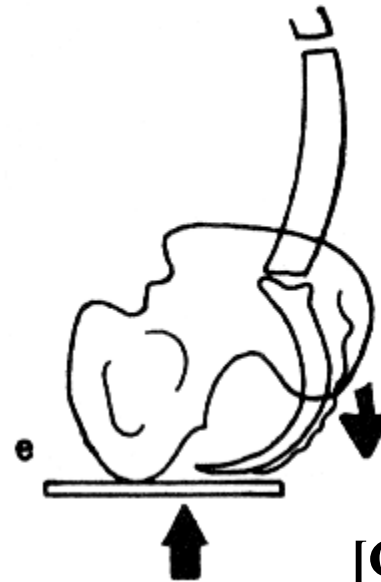
**SITTING  
ERECT  
(sacrum  
support)**



**SITTING  
(leaning  
forward)**



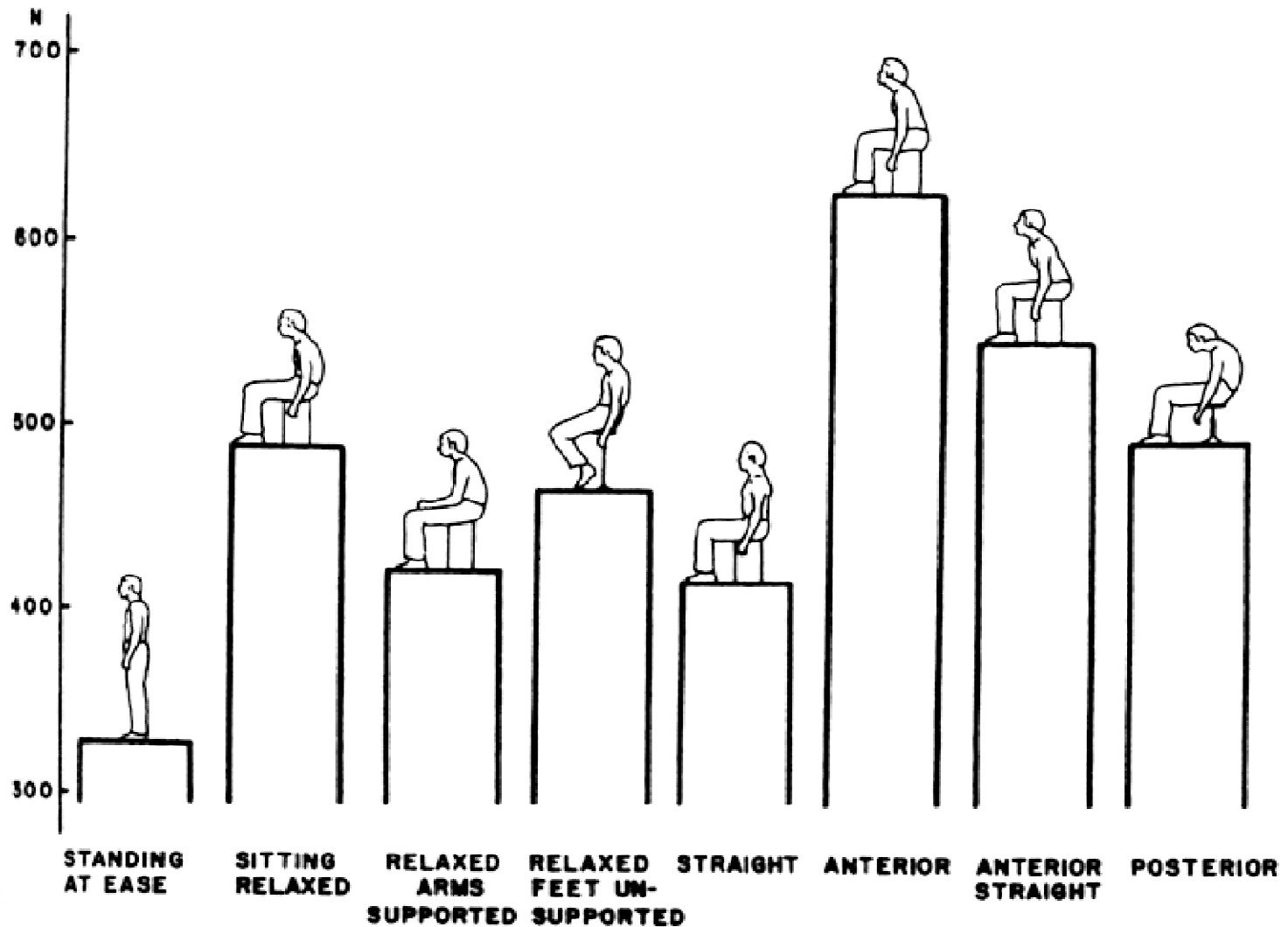
**SITTING  
(leaning  
back)**



[Chaffin et al., 1999]

# *Chair and Disc Force*

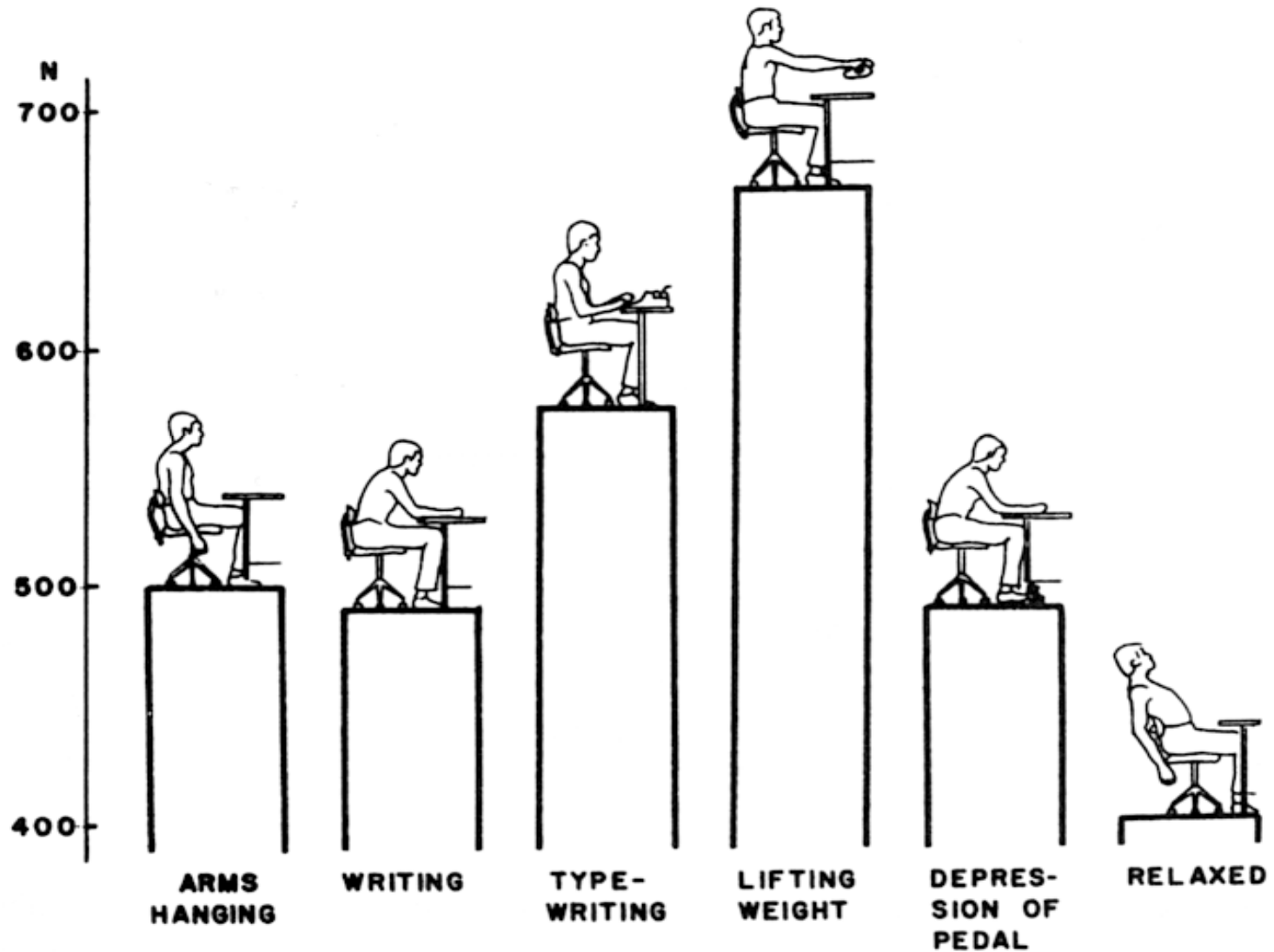
**Disc  
Force**



[Andersson et al., 1974a]

# Office Desk and Disc Force

**Disc  
Force**




[Andersson et al., 1974b]

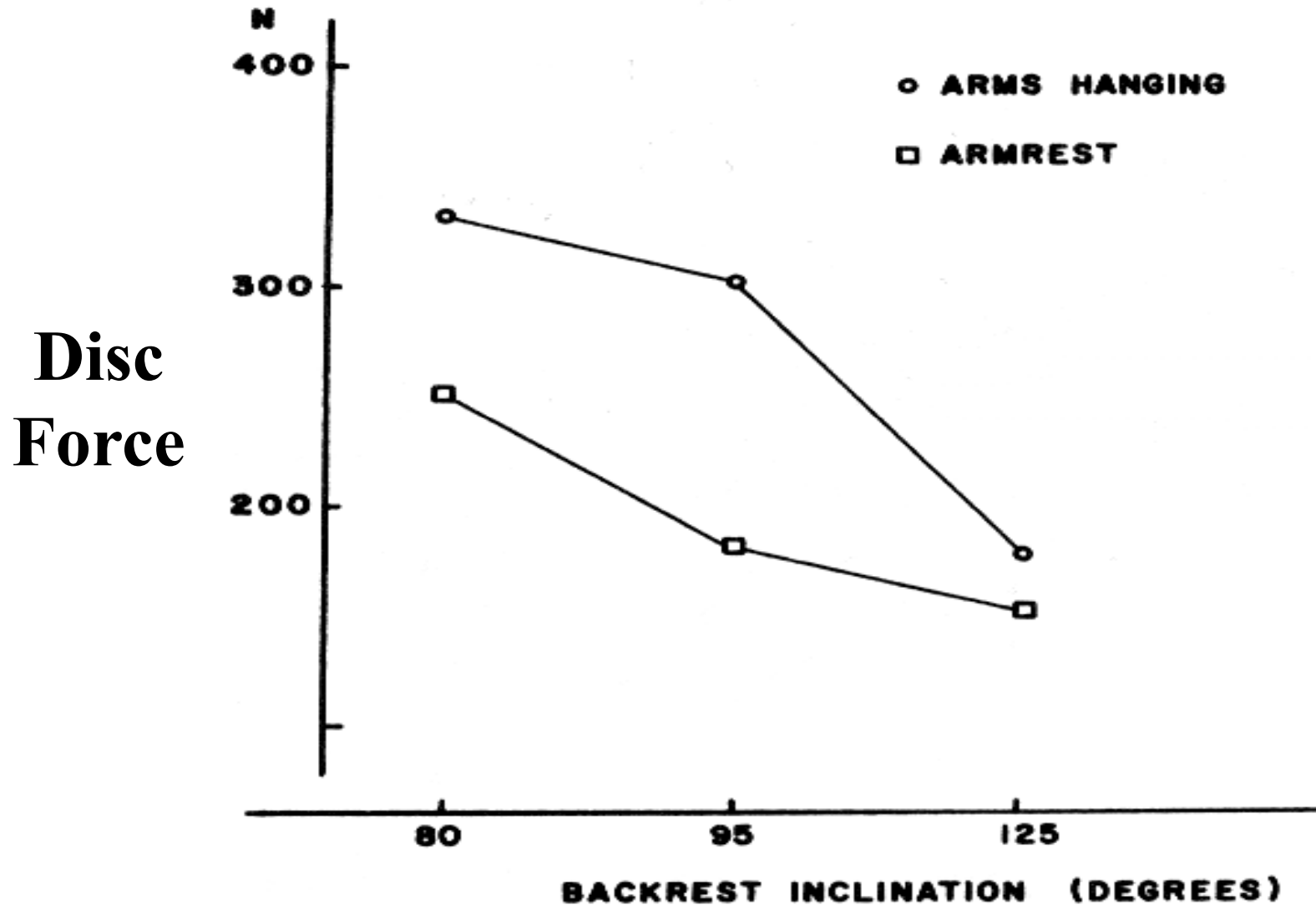
# ARM RESTS



- The importance of arm rests is often underestimated
- Arm rests unload the shoulder girdle
- Weight of the arms is *10 %* of body weight
- Variety of arm positions
- In cars, arm rests are often absent or too low

- 
- A proper arm rest must be placed below the mass centers of upper and lower arm
  - In cock pits for pilots= adjustable arm rest
  - Logical error= air passing underneath, only limited area supported


# *Armrest and Disc Force*




[Andersson et al., 1974a]

# Back Rest

- Provides stability for the vertically erected trunk
- In prolonged sitting, the prevention of a lumbar kyphosis → most important function of the back rest
- Click-clack phenomenon

- 
- Lumbar Lordosis is the result of a mass center of gravity of the trunk at the ventral side of the ischial tuberosities .
  - The mass center of gravity of the trunk dorsal to the **ischial-tuberosities** forces the lumbar spine into kyphosis
  - The latter can be prevented by the exertion of lumbar support on the upper side of the pelvis and the lumbar spine.



- 
- The function of a lumbar support is to exert a firm force on the upper side of the pelvis and the lumbar area to prevent tilting in kyphosis

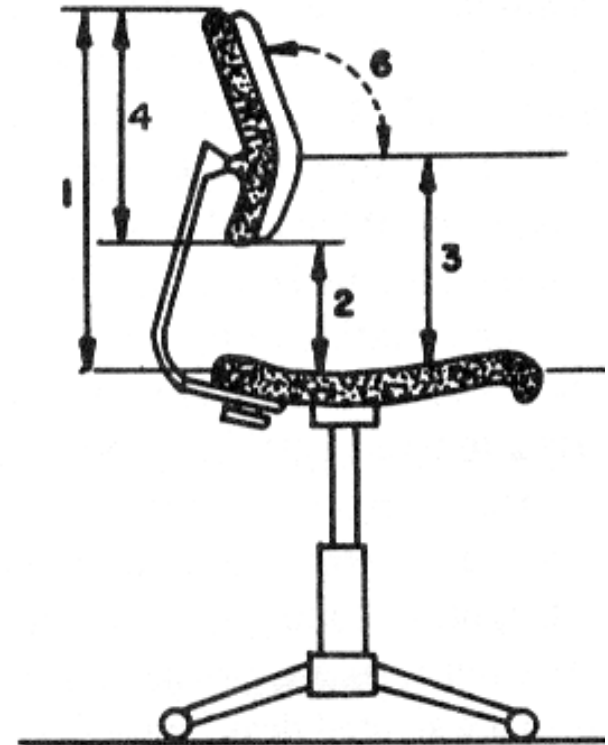
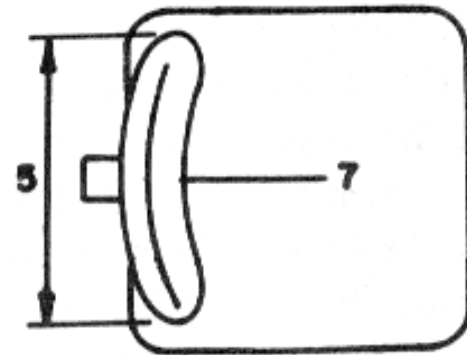
- 
- Support should not reach higher than the lower edge of the scapulae.

### **Reason**

- The thoracic spine is stiff enough (ribs) and a higher back rest pushes the shoulder blades forward, which overrules the lumbar support and hinders the shoulders to stretch and to turn to the left and the right
- The absence of a back rest, like sitting on a crutch always leads to a C-form of the spine

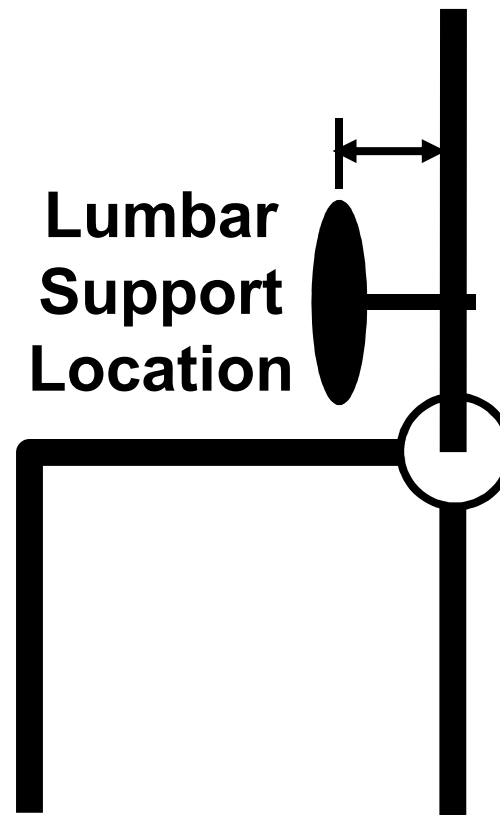
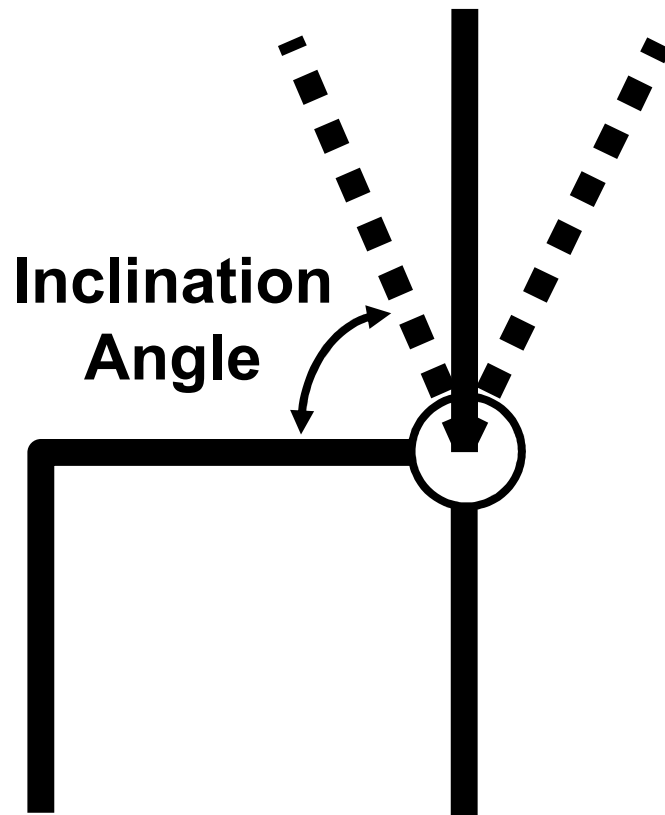
## Backrest Dimensions

1. Top height
2. Bottom height
3. Center height
4. Height
5. Width
6. Horizontal radius
7. Vertical radius
8. Seat angle

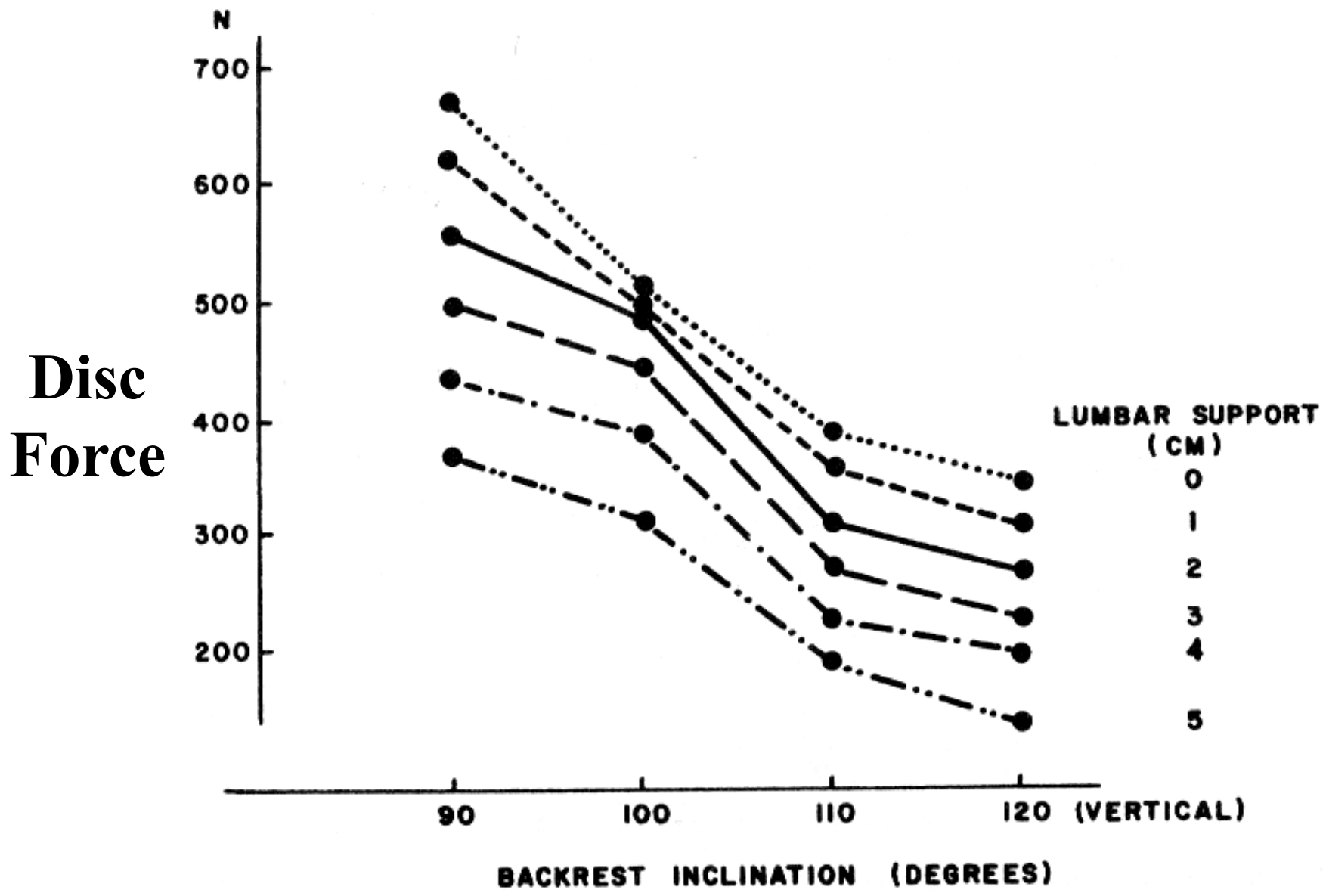


[Chaffin et al., 1999]

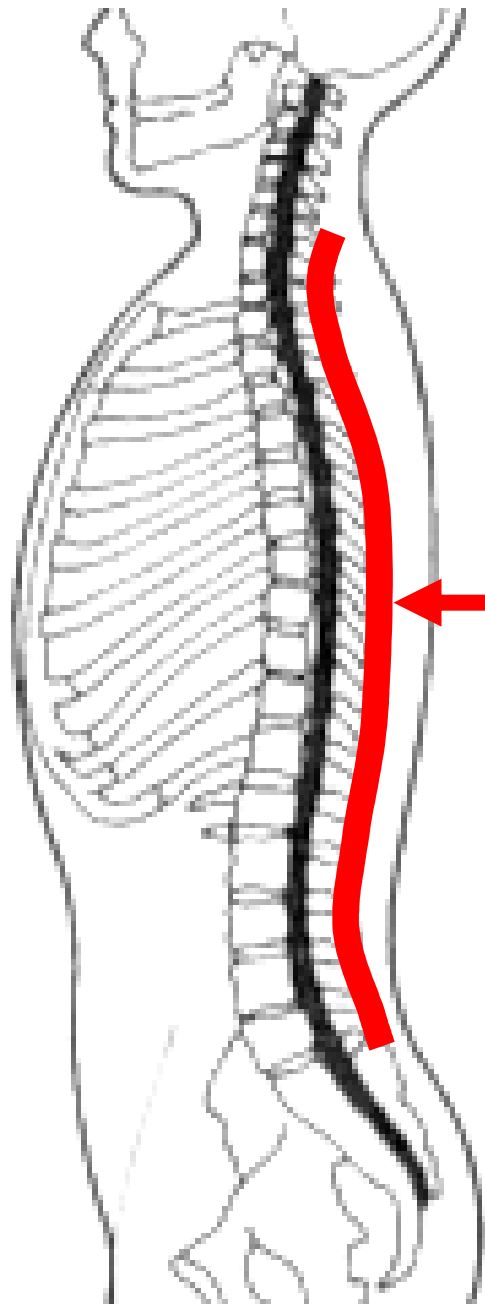
# *Backrest and Lumbar Support*



# Backrest, Lumbar Support, & Disc Force



[Andersson et al., 1974a]



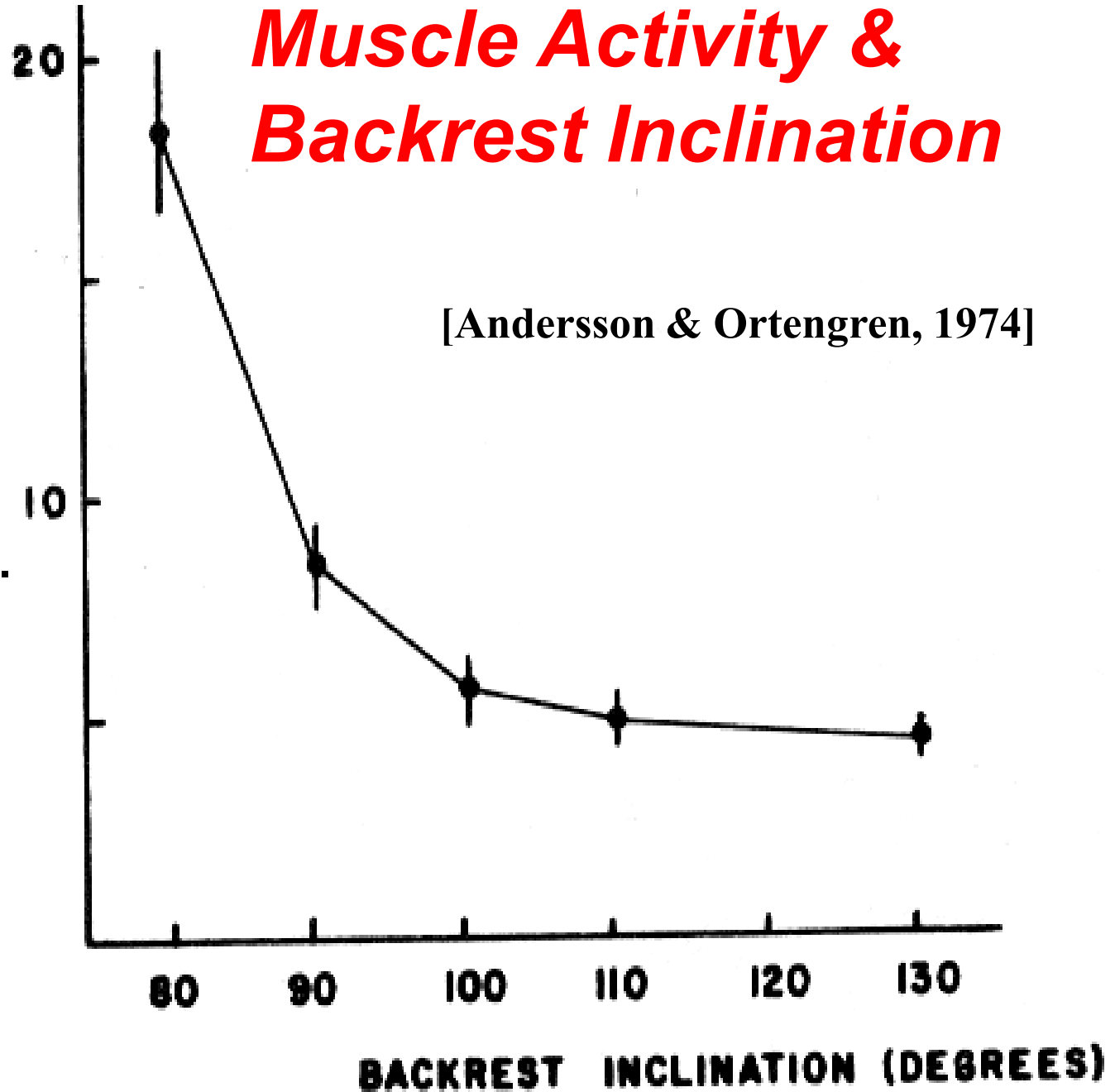
## **Erector Spinae Muscle**

- Extends down the back
- Involved in lateral (sideways) flexion of back & extension activities, e.g. maintaining back posture in any “sitting” position
- The greater the EMG (electromyography) muscle activity, the greater the compressive force on discs

# ***Muscle Activity & Backrest Inclination***

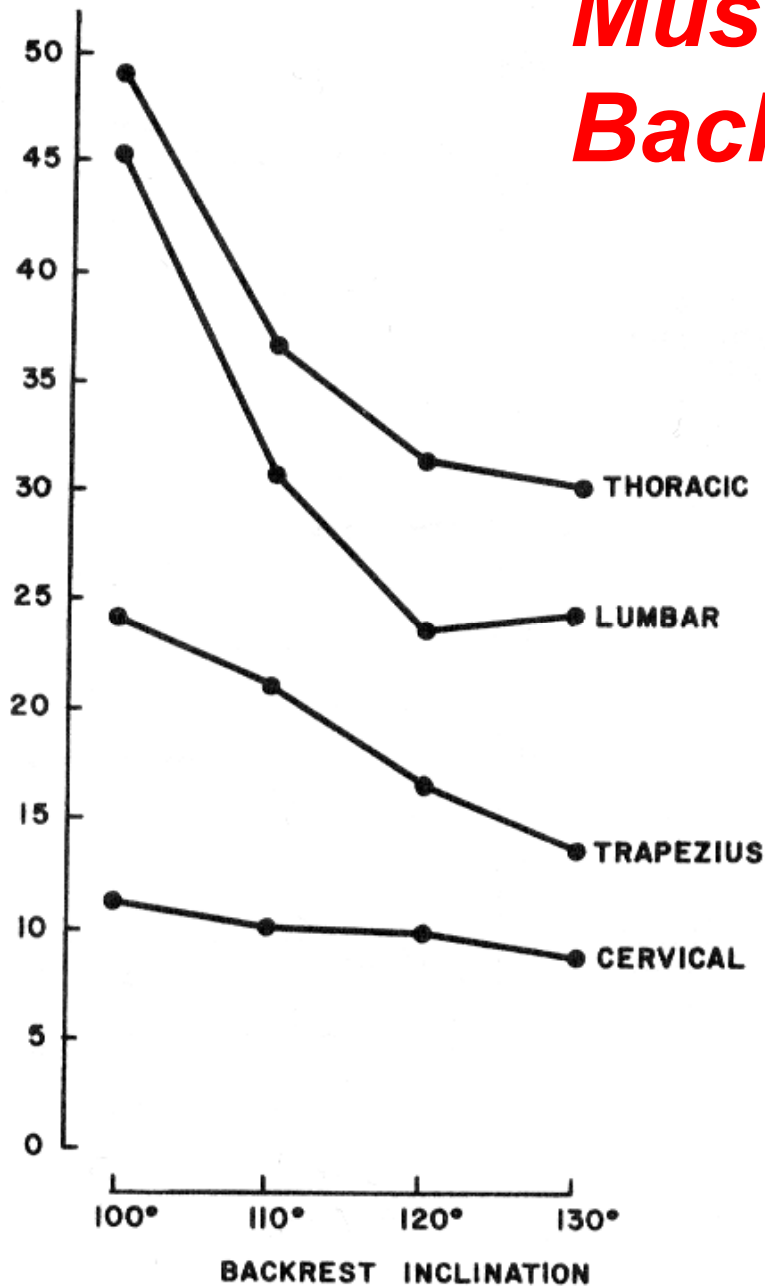
[Andersson & Ortengren, 1974]

EMG signal in lumbar erector spinae muscles.



## ***Muscle Activity & Backrest Inclination***

**EMG**  
(Arbitrary  
Units)

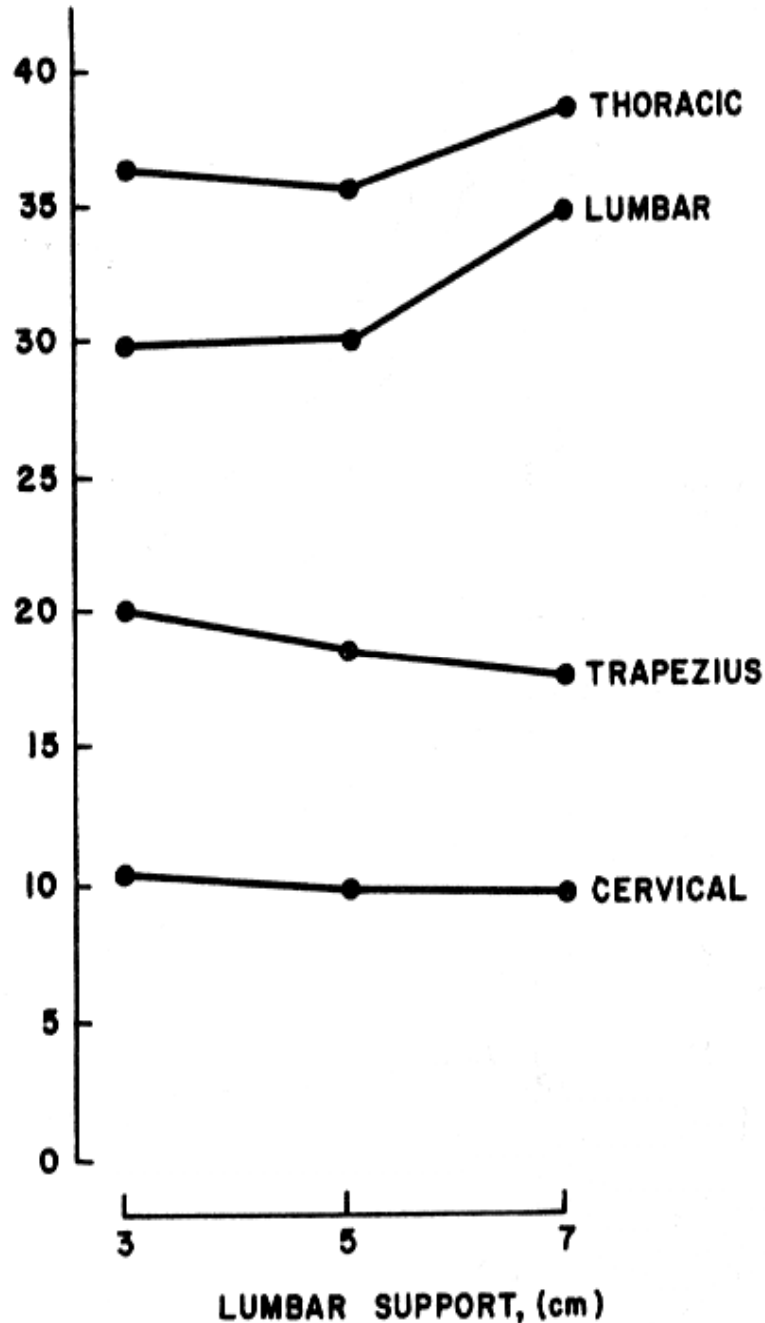


Increased backrest inclination lessens the need for spinal support from the erector Spinae muscle, thereby lowering its EMG activity (Hosea, 1986).



## *Muscle Activity & Lumbar Support*

**EMG**  
(Arbitrary  
Units)



Change in lumbar support has varying effects on EMG erector spinae muscle activity at different spine segments (Hosea, 1986).

# Seat

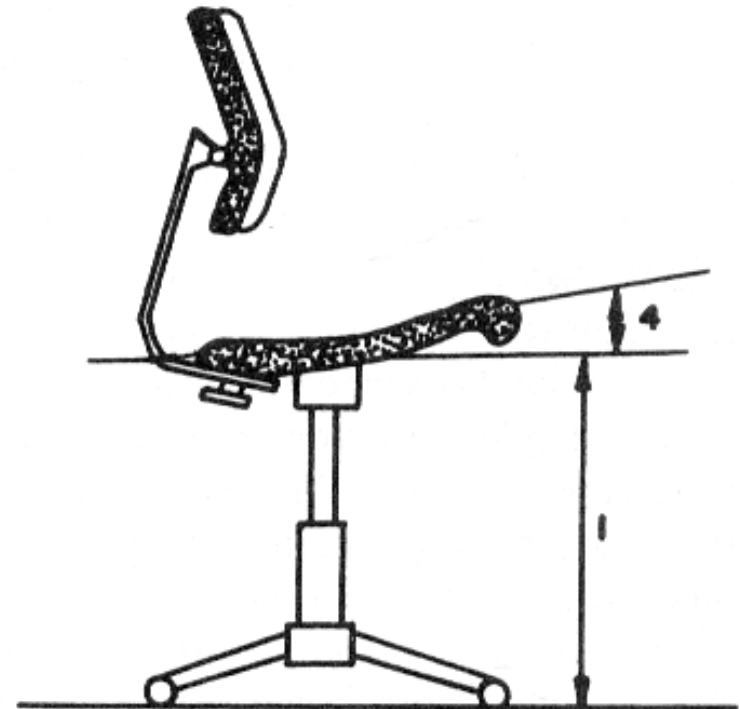
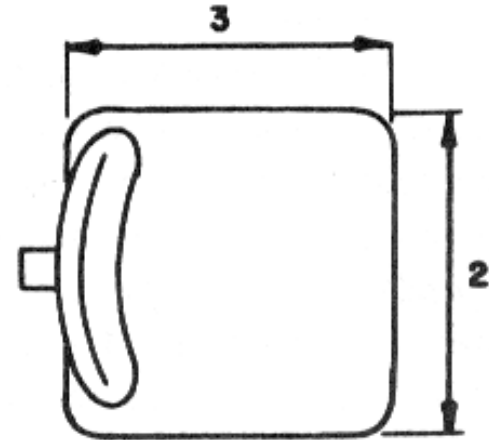


- The weight of the trunk, head, and part of the arms is almost completely carried by the ischial tuberosities
- Horizontal seat always raises friction at the ischial tuberosities, this friction can be completely eliminated by:
  - means of a moderate seat angle and that the angle between seat and back rest is optimal between 90 and 95°

- Back rest inclination is larger in auditoriums, cars, and easy chairs at home
- This facilitates a horizontal direction of looking and has the advantage that the back rest contributes in carrying the trunk
- Head rests cannot carry the head when they are positioned too far forward

## Seat Dimensions

1. Height
2. Width
3. Depth (length)
4. Slope



[Chaffin et al., 1999]

# Chair And Table




- ❑ A chair is important for a good posture
- ❑ In tasks such as reading and writing are involved, the height and inclination of the desk or table play a dominating role
- ❑ Despite good chairs, postures with the back bent, sagging, or twisted can be observed
- ❑ Vicious cycle of pain

# Leg-crossing



- The majority of people cross their legs often when sitting, alternating left over right and right over left
- There may be many reasons to do this, but in the literature there is no scientific proof about the benefit or demerit of leg-crossing


- 
- Less activity of the internal oblique abdominal muscles
  - By crossing the legs, an alternative and less fatiguing means is found for self-bracing of the SI joints


# Lying





- *A bed is a body support surface on which prolonged and complete rest must be found*
- Combination of a mattress, a mattress carrier, and a bed frame or bedstead
- Spread-out mat on the floor
- Several kinds of mattress carriers



- 
- **A good bed** should
    - ▣ Adapt *to* body curvatures
    - ▣ Remain flat
    - ▣ Have a pleasant spring action
    - ▣ Have good ventilation, and
    - ▣ *Not* be too warm or *too* cold
  - Aspects 1 to 3 concern body support that evenly spreads the pressure on protruding (bony) parts.
  - Gives a **straight spine** when lying on the side, and gives a natural **S-shape** to the spine in the supine posture

- 
- For static equilibrium, muscle action is superfluous
  - For separate support of the head, a **pillow** is needed.
  - The thickness of the pillow is related *to* the curvature of the spine
  - **Thin vs. thick pillow**
  - Pillows must be pliable *to* also support *the* neck.


- 
- A bed that is too hard results in **restless change of posture** to unload areas with disturbed blood flow.
  - Normally people change posture **20 times per night**
  - The most unconstrained form of the lumbar spine is found when the angle between the trunk and femur is **135 degree**

- 
- **Muscle running from the lumbar spine to the femur:**  
Psoas major, part of the iliopsoas can be shortened, which raises tension in this muscle and causes a hollow back in supine posture
  - Improved by **exorotation** of the legs and, if this is insufficient, by **lying on the side**.
  - When lying on the side, the spine should not bend laterally resembling the scoliotic form

- 
- This occurs in persons with pronounced **waists** and little give of the mattress region of the shoulder and the hip

# Sitting In Bed

- Sitting in bed is common, especially in **hospitals** in which the head portion can be raised upward
- Sitting in bed on a horizontal mattress gives rise to **shear forces** (in the order of magnitude of 100 N) on the skin and underlying tissues of the bottom.
- As a consequence, the pelvis moves little by little on the mattress


- 
- **Taller people** have the advantage that they can come to a stop with the feet against the board at the foot end
  - lumbar support is absent, which causes **lumbar kyphosis** and the pelvis to rest on the os- coccyx instead of on the ischial tuberosities.
  - The combination of pressure and shear is a provocation of **decubitus skin ulcerations**


# Decubitus



- Prolonged pressure (without shear) of 35 to 40mm Hg (4.6-5.3 kPa) can be tolerated.
- Shear decreases the **tolerable pressure** considerably
- Sitting in bed is a provocation of decubitus skin ulcerations, which can be solved by **tilting the mattress**



- 
- The medium for **anti decubitus mattresses** can be divided in four groups:
    - Solid material
    - Fluid
    - Gas
    - Combination of these media

- 
- **Solid materials** are foam, sheepskin. woolen blankets, etc.
  - Deep impression of the material results in a larger force
  - The ideal material should have a horizontal (isotonic) and adjustable spring characteristic.
  - **Gas** allows for the application of equal pressure along a large surface

- 
- Greater shear stresses in **fluidized surface**
  - "Air-fluidized" beds