Biomechanics
Chapter 2

P&O UMTY 2019

Prepared by Markku Ripatti

Terms and Definitions of some basic concepts of biomechanics

- Biomechanics
- Gravity
- Force
- Reaction force
- Ground Reaction Force
- Centre of gravity
- Stability
- Pressure
- Moment

Effect of weight bearing surfaces

- Horizontal and sloped surface

TT socket Biomechanics

- Total Contact
- Pressure Distribution concepts

What is biomechanics?

Biomechanics= Bio + Mechanics

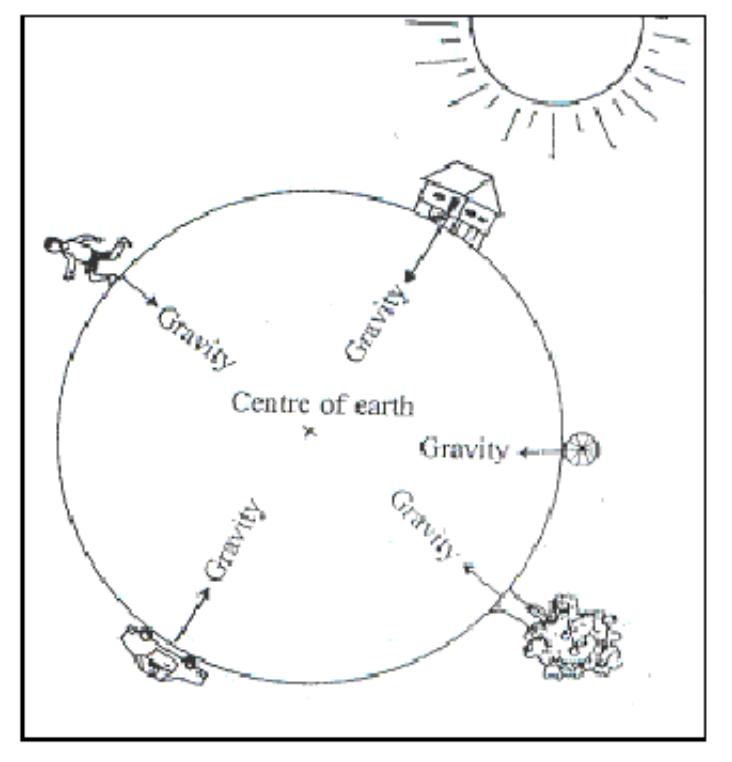
- Bio = related to living thing
- Mechanics = related to forces

- Biomechanics is the applications of the principles of mechanics to the system in the human body.
- The study of forces acting on the human body during daily activities (walking, standing, etc).

Why study biomechanics?

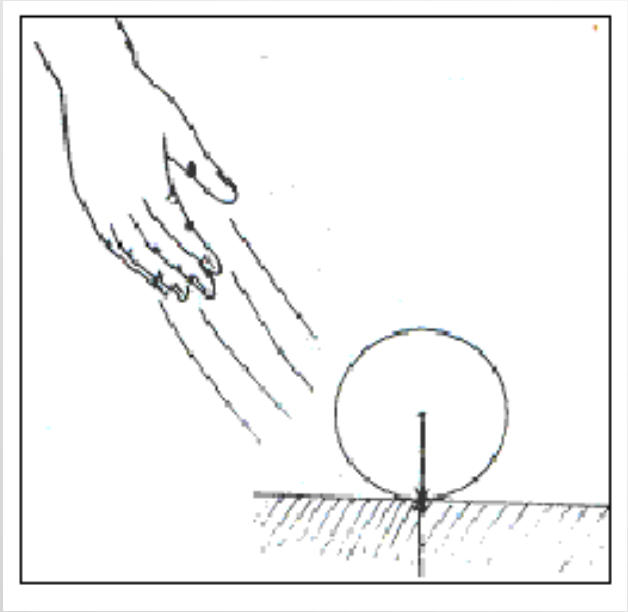
- To understand the proper alignment of prosthesis
- To be able to align the prosthesis in proper alignment
- To understand the concept of pressure
- To understand the relationship between pressure and alignment
- To get comfortable socket fit for the patient

What is gravity?



- **Gravity -** Big things "pull" small things toward them.
  - Eg. The Sun pulls the Earth and the Earth pulls on us.
- Things affected by gravity have "weight" – the force that pulls them down.
- The force that makes us stick to the ground
- The force that makes objects fall to the ground

Gravity

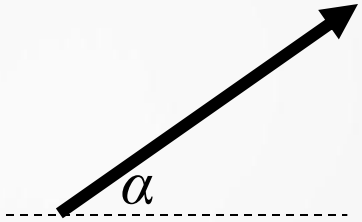


- When the object drops, gravity pulls it to the ground
- When the object reaches the floor it stops because there is an opposed force from the ground that call Ground Reaction Force (GRF).

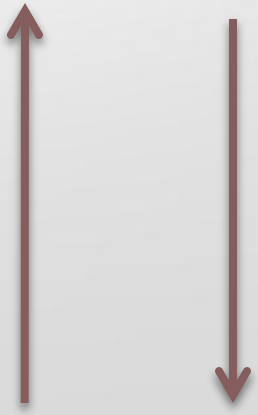
Directions

- Plumb line represent the direction of gravity
- It is called **vertical**

- **Horizontal** line is the line that is 90 degree to the vertical line

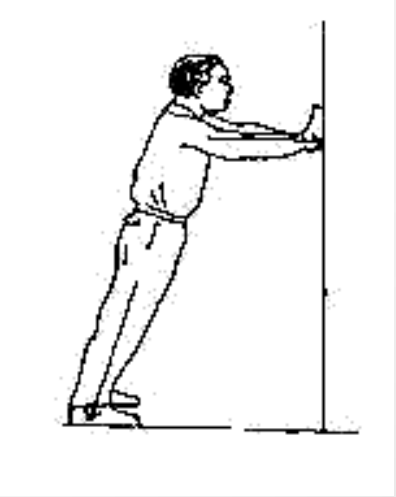


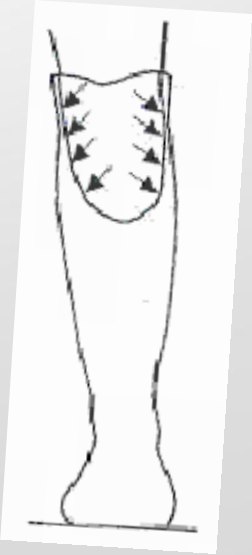
- **Oblique**
- **Parallel lines** never meet



What is force?

- A force is a push or a pull on an object.
- Weight of an object is gravitational force
- Unit? (Newton=N)
- People lean to the wall to create a push (force)
- The weight of the body also applies force to the ground
- When an amputee wears a prosthesis, his weight applies force to the prosthesis

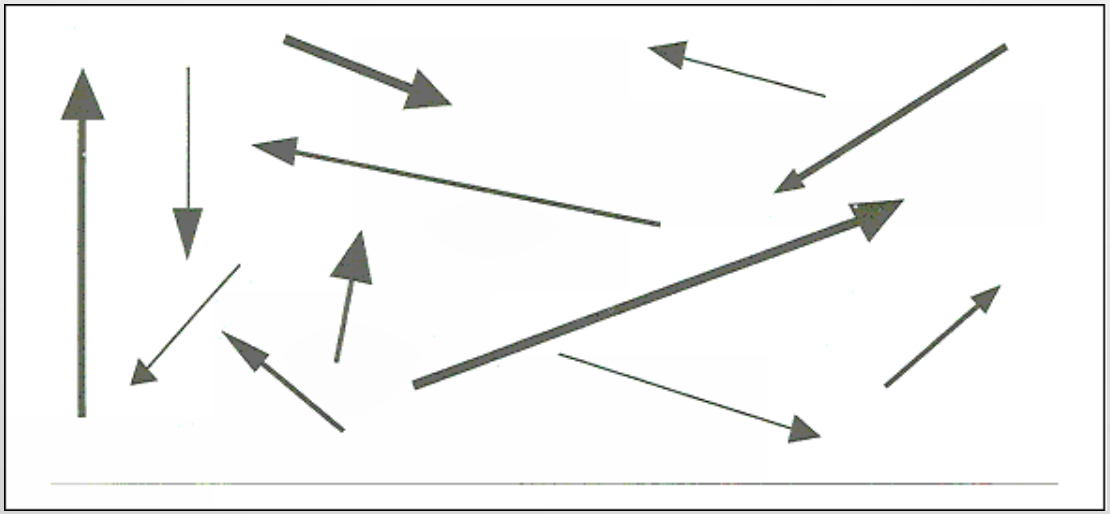




Characteristics of force

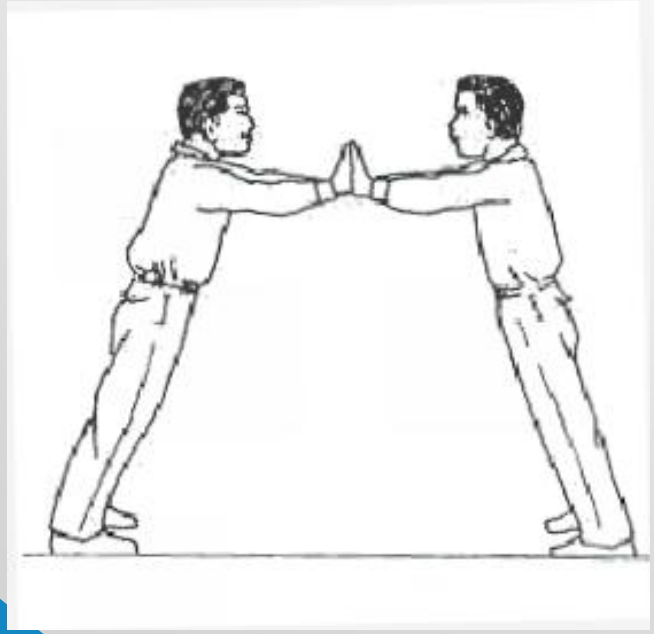
- Magnitude (size)
- Action line
- Direction
- Point of application

- Magnitude is illustrated by the strength or length of the arrow below
- The way of arrow points shows the direction of force



Reaction force

- Every force that does not create movement means there is an equal and opposite reaction force



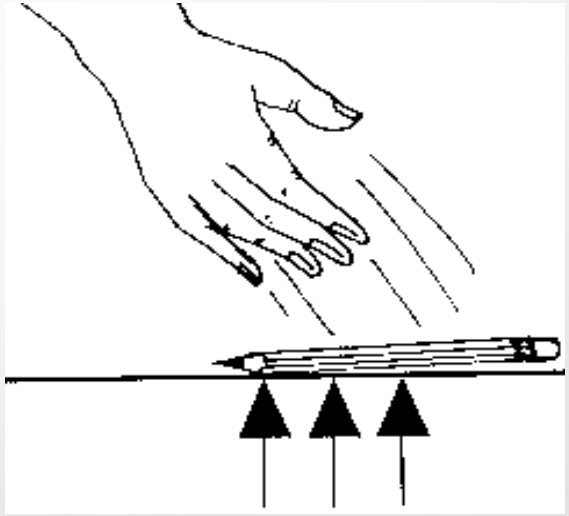
- Amputee weight is balanced by the reaction force from the prosthesis

No reaction force

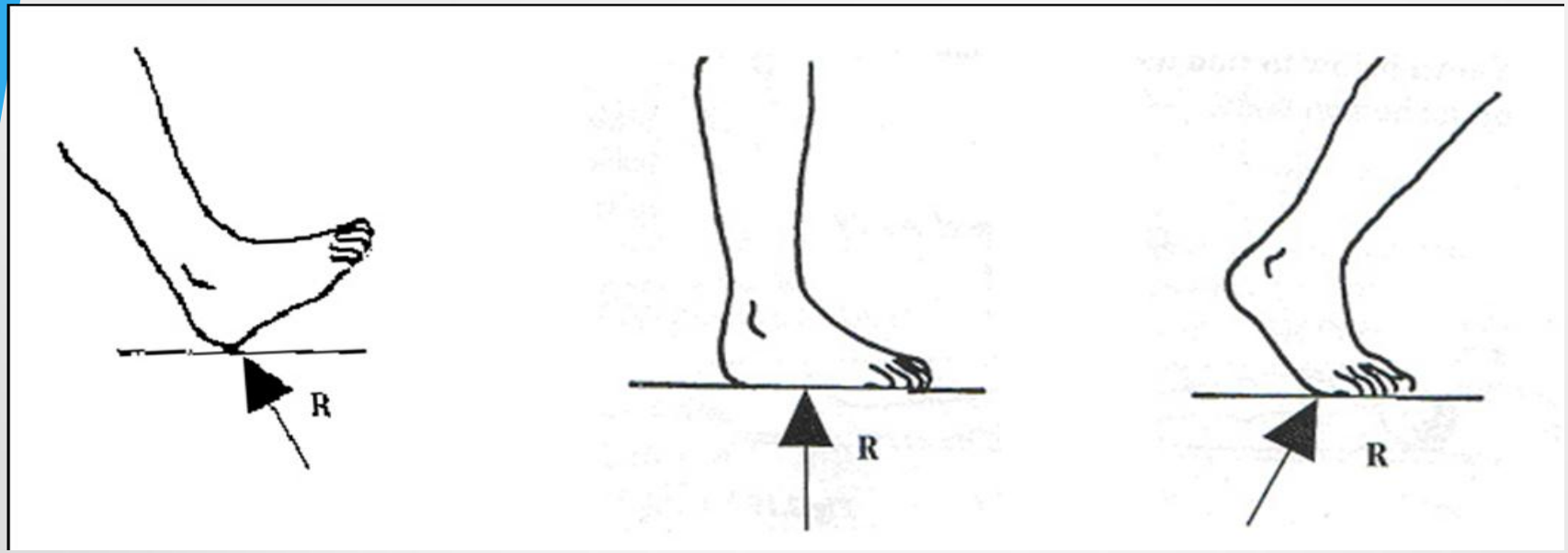
Fig 2.12

Ground Reaction Force (GRF)

- GRF is equal and opposite to the weight of an object
- During standing, the person weight applies a force to the ground, and the ground applies a GRF to the body
- If the ground was not pushing back, we would fall through it



Ground Reaction Force (GRF)



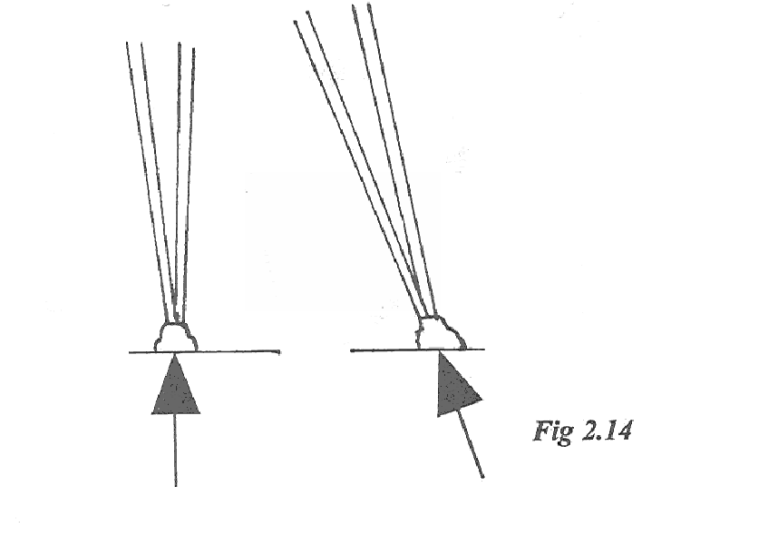
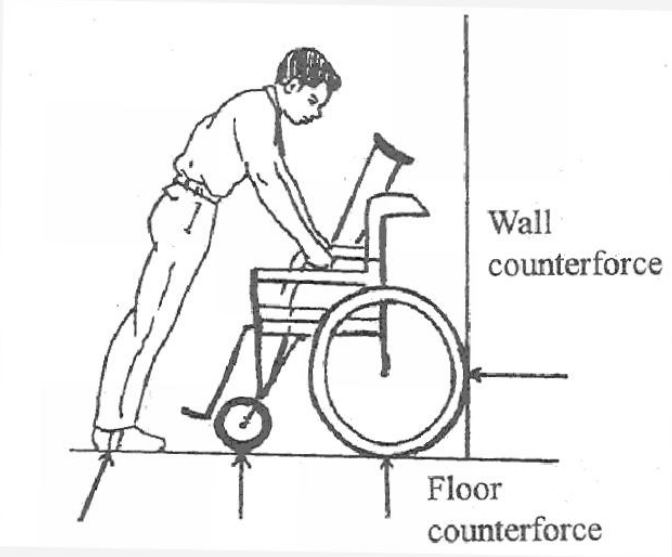
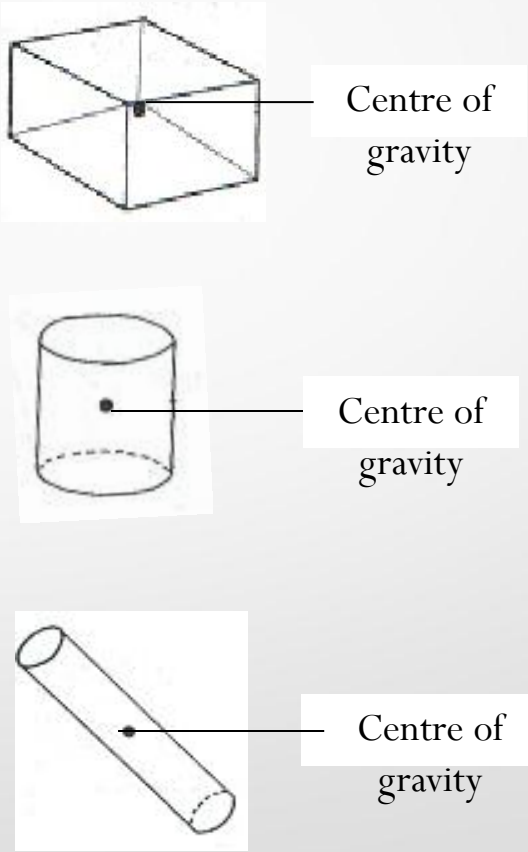


Fig 2.14



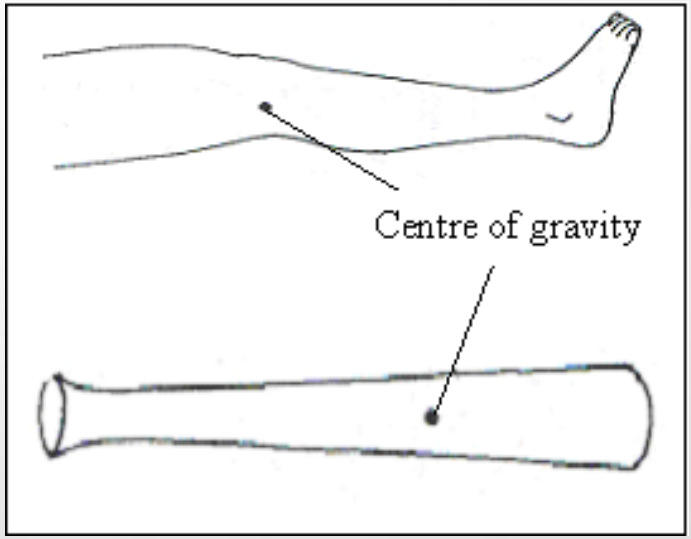
Centre of gravity

- Centre of gravity is the point at the centre of mass
- It is a balance point
- Weight-line is a vertical line from the CoG of the body down to the ground



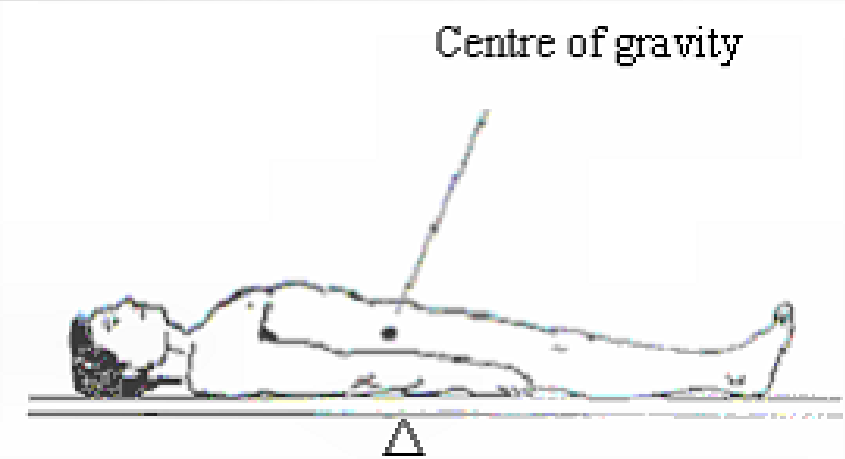
Centre of gravity

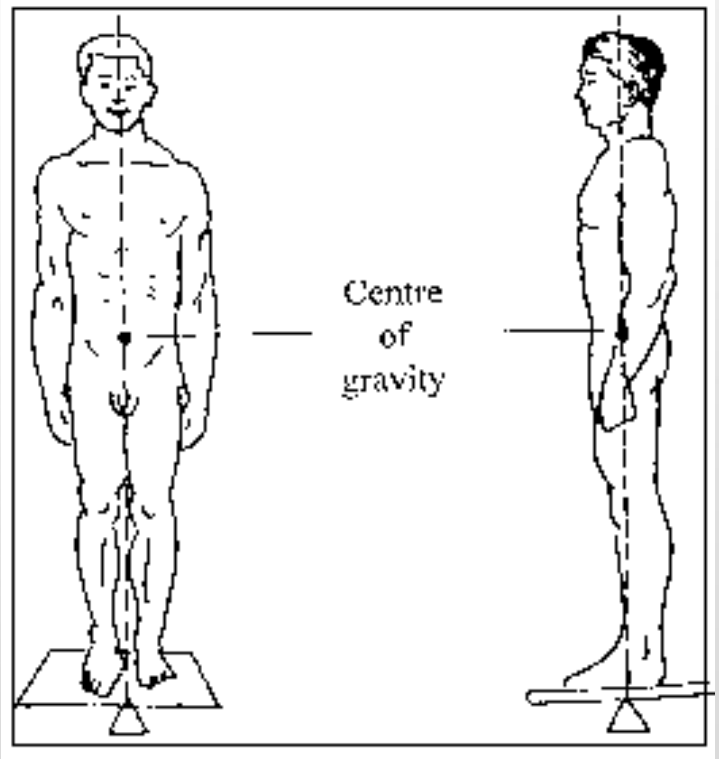
In case the mass is not symmetrical, the center of gravity will be closer to the larger and heavier end.



Human Centre of Gravity (Borelli method)

Centre gravity of the human body lies within the pelvis (in front of S2)



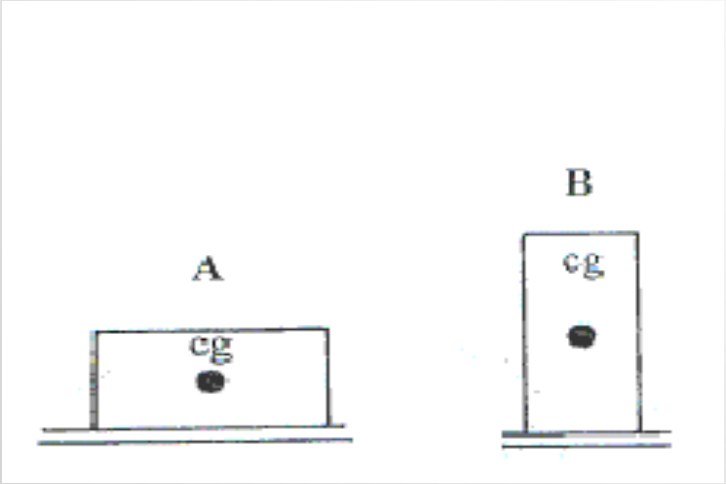


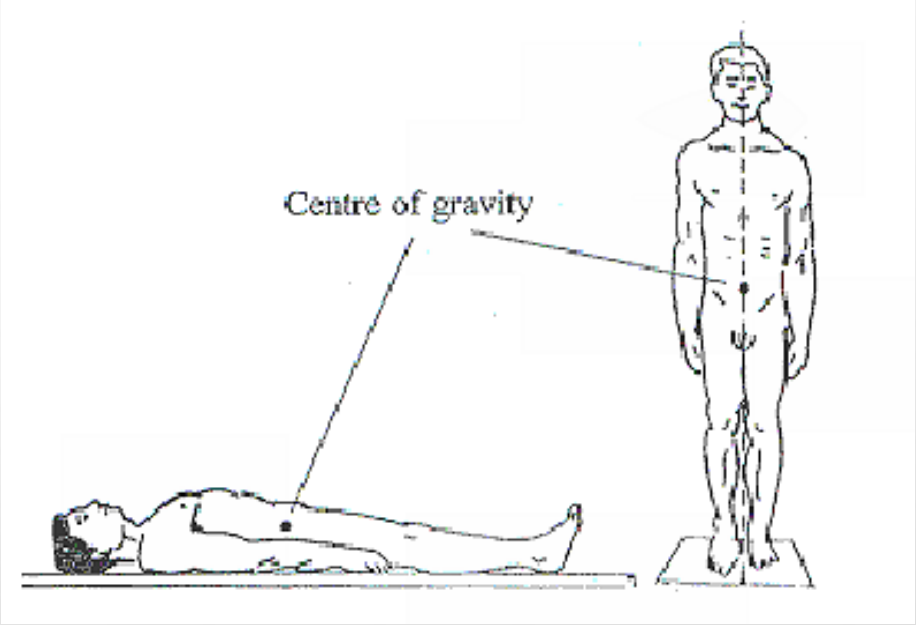
Stability

- Stability is the ability to remain fixed, permanent, unchanged or invariable. Its resistance to "fall over".
- Three main factors of stability

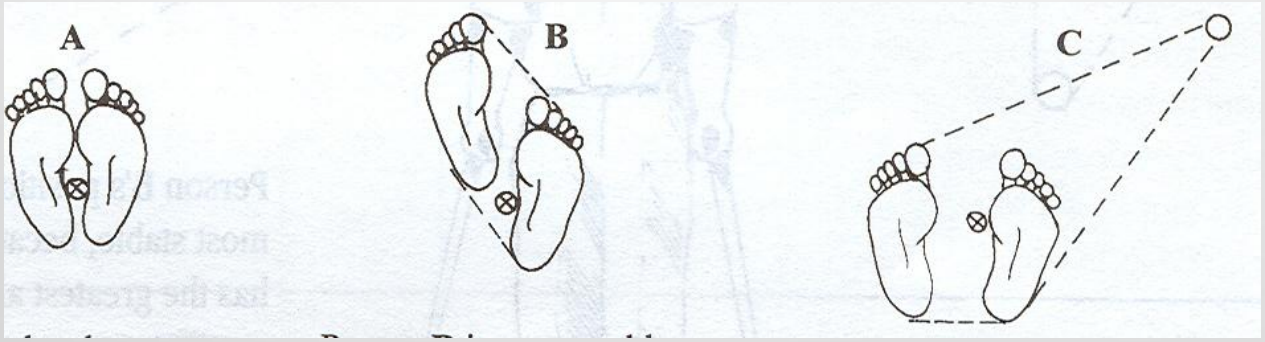
1. The height of object's centre of gravity over the base support
2. The size of the base support
3. Where of centre's of gravity in relation to the base support

Height of Centre of Gravity

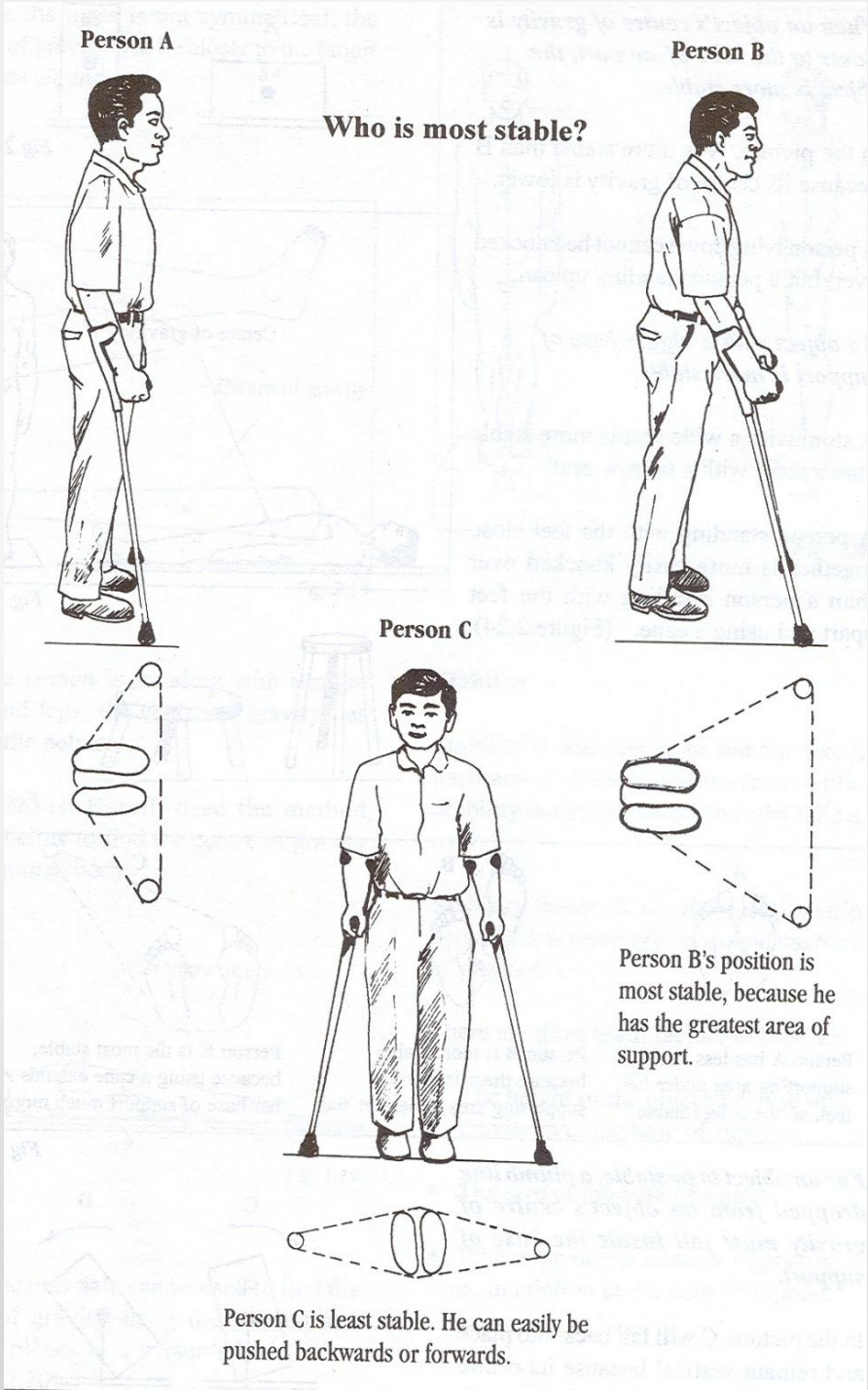




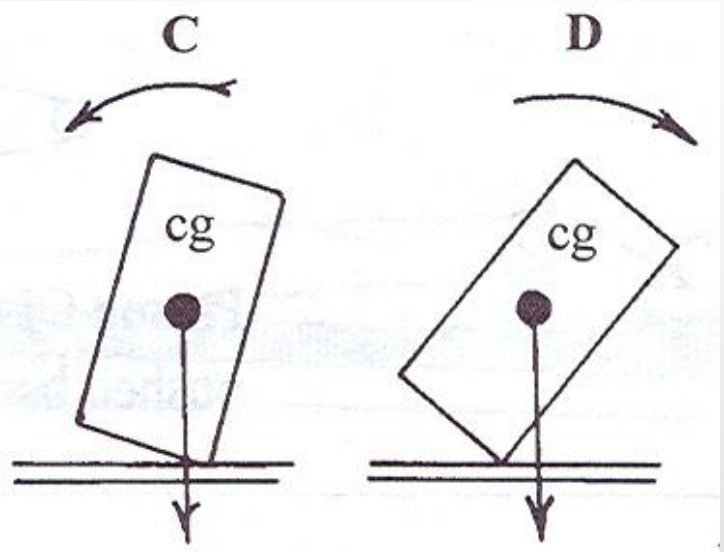
Base of Support

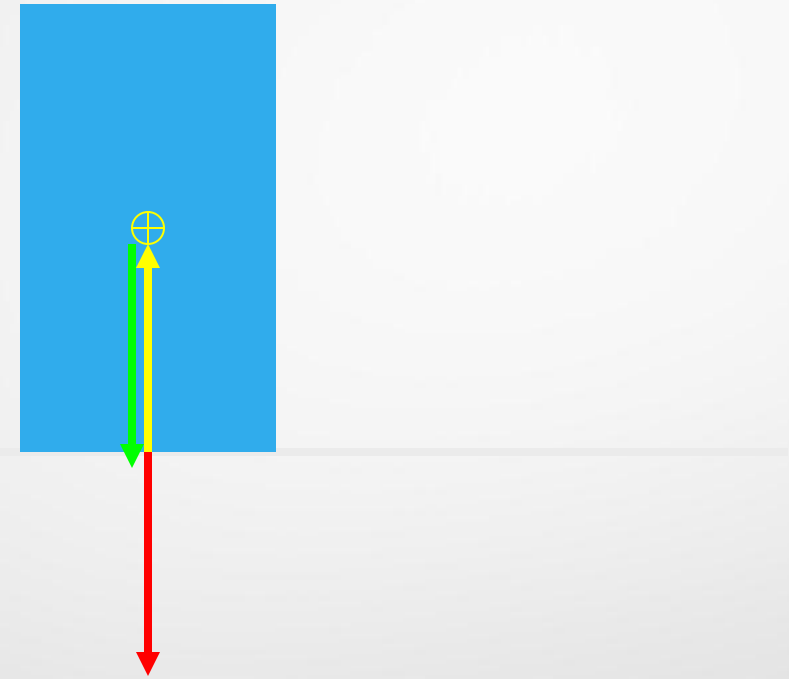


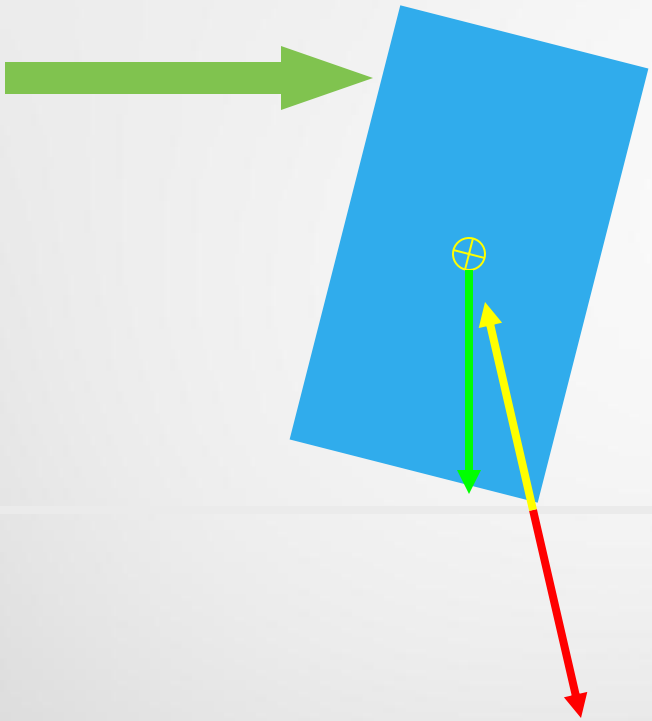
Stability

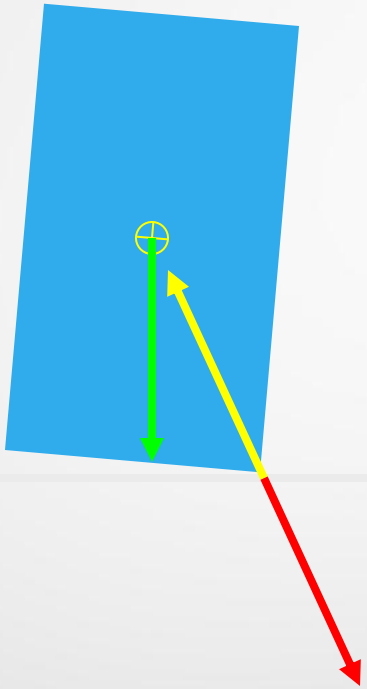

Person A
Person B
Who is most stable?
Person C
Person B's position is most stable, because he has the greatest area of support.
Person C is least stable. He can easily be pushed backwards or forwards.

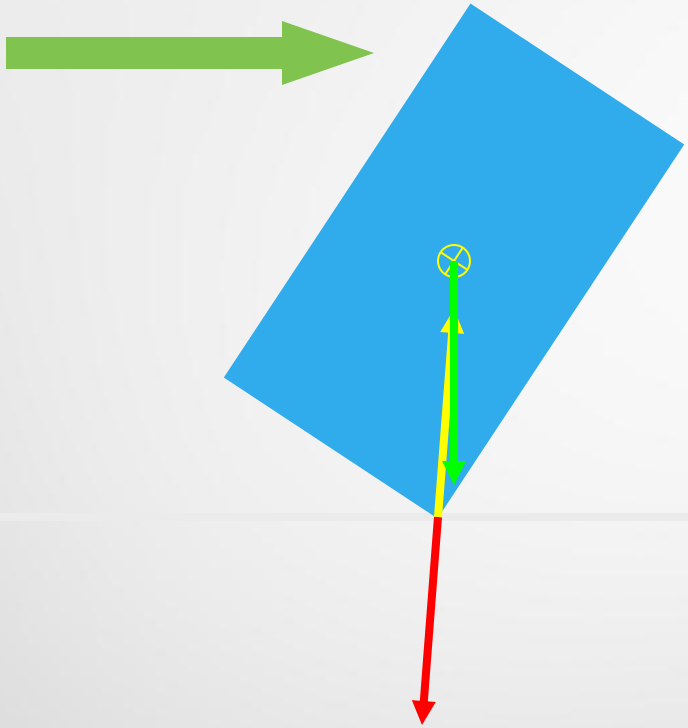
Relation between CoG and Base of support

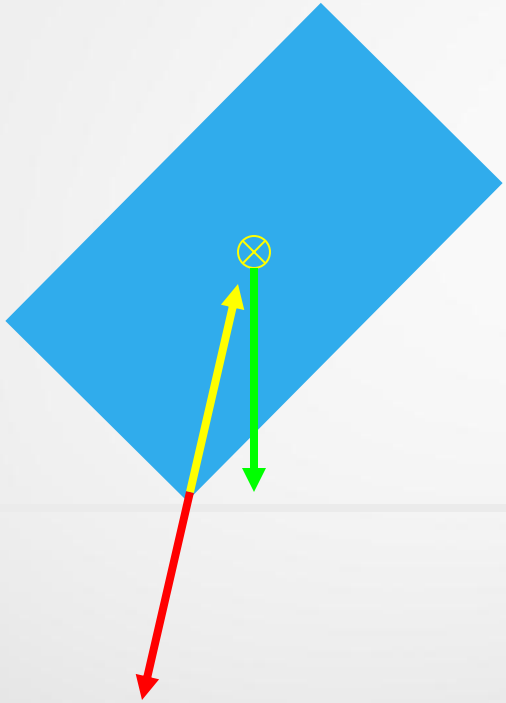


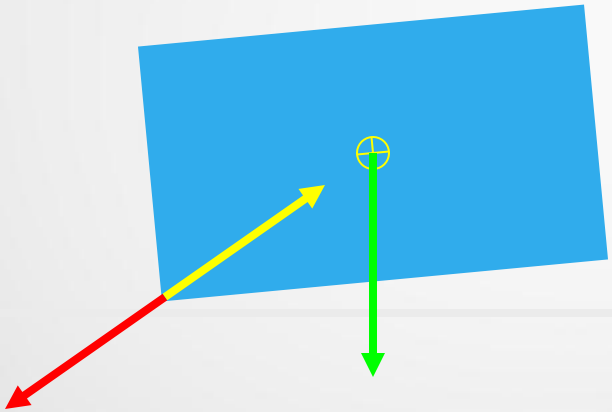






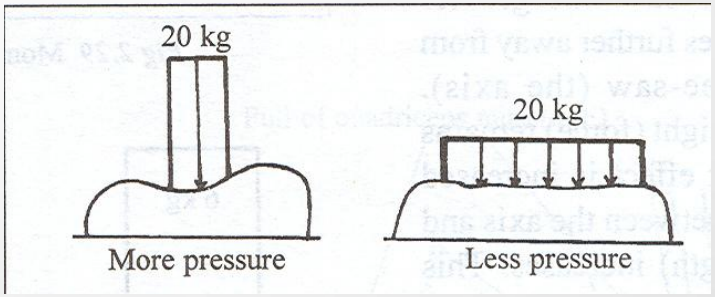


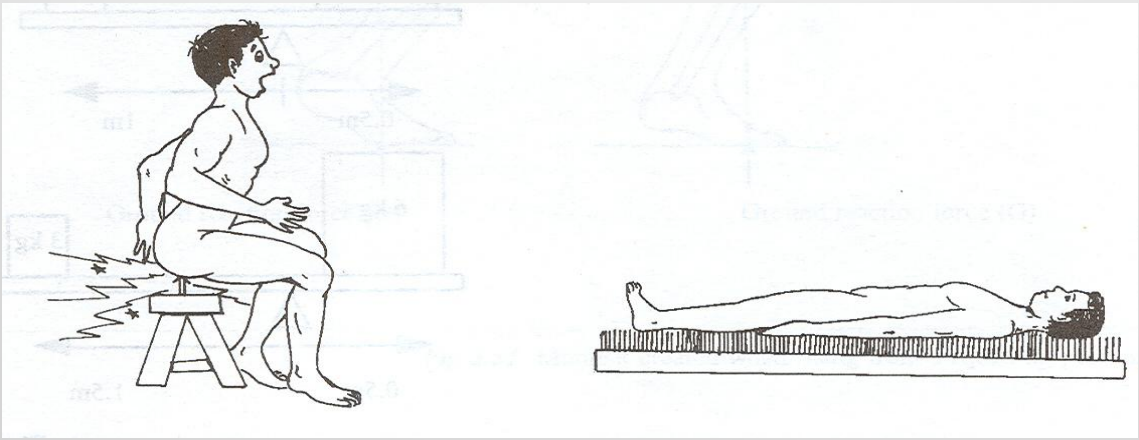




Pressure

- Pressure on the stump is very important for making comfortable prosthesis
- Pressure depends on the magnitude of force and the area that the force are applied
- Pressure = Force/Area
- Big area ⟶ small pressure





Pressure

Pressure is force per unit area

P = Force/Area, Unit of P is N/m^2 or Pa

For an object sitting on a surface, the force pressing on the surface is the weight of the object.

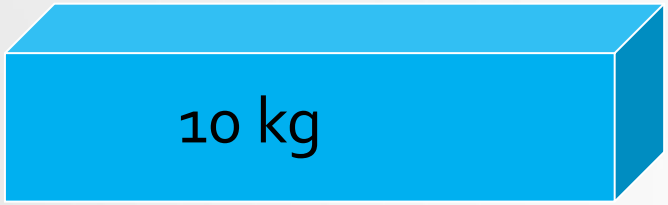
Big pressure causes

- Skin break down, ulcerated areas and pressure sore

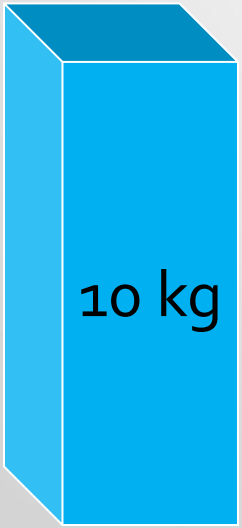
To avoid big pressure on the body

- Increase size of area

Useful terms



Area = 0.1m²
Pressure = 1000 N/m²

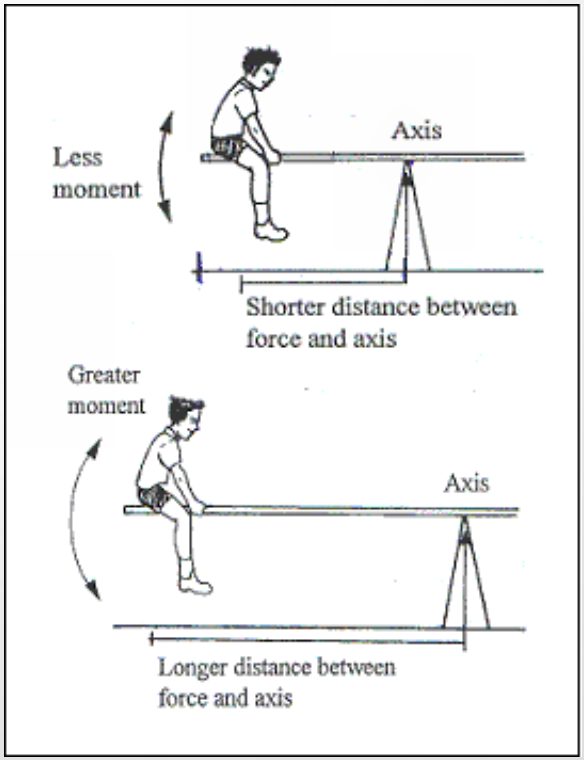


Area = 0.01m²
Pressure = 10000 N/m²

Same force, different area, different pressure

Moment

- Moment is a turning effect of a force around an axis
- Moment=Force*Lever arm (perpendicular length of force to axis)
- Moment depends on the size of force and length of lever arm

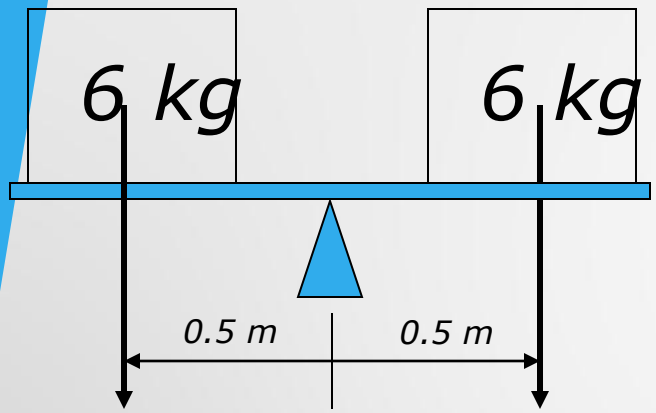


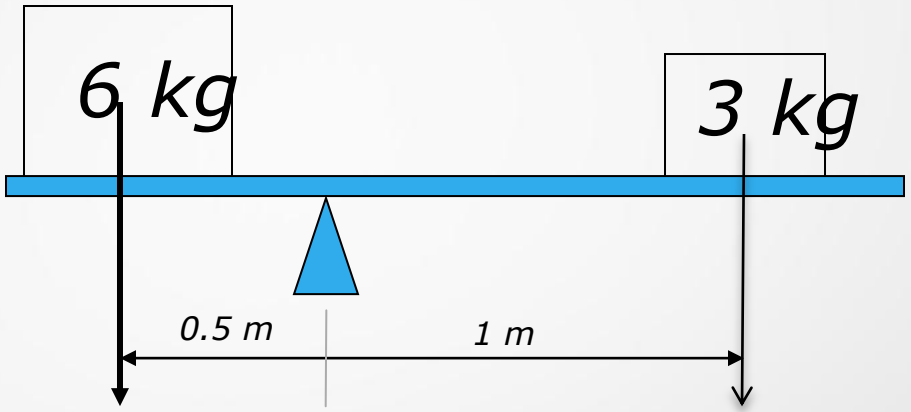
Distance from F to axis

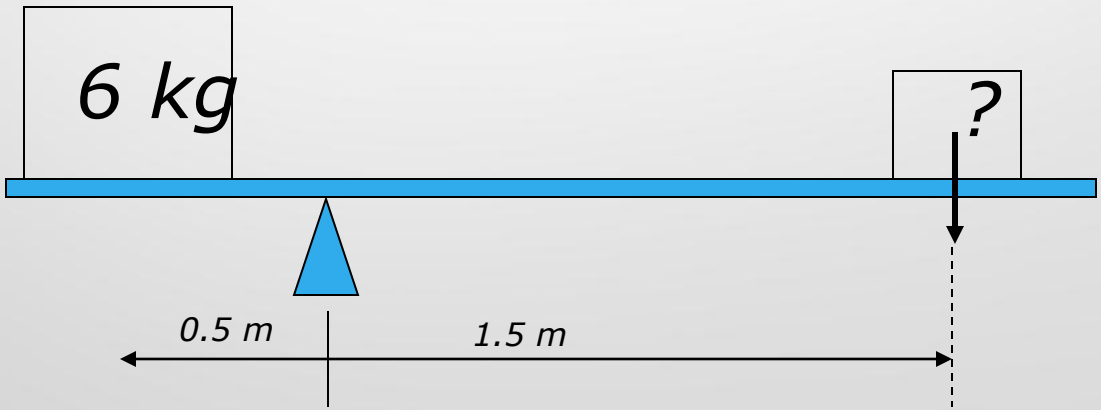
- Shorter causes **less M**
- Longer causes **greater M**

When NOT in balance, system rotates in direction of higher moment

Balance moment

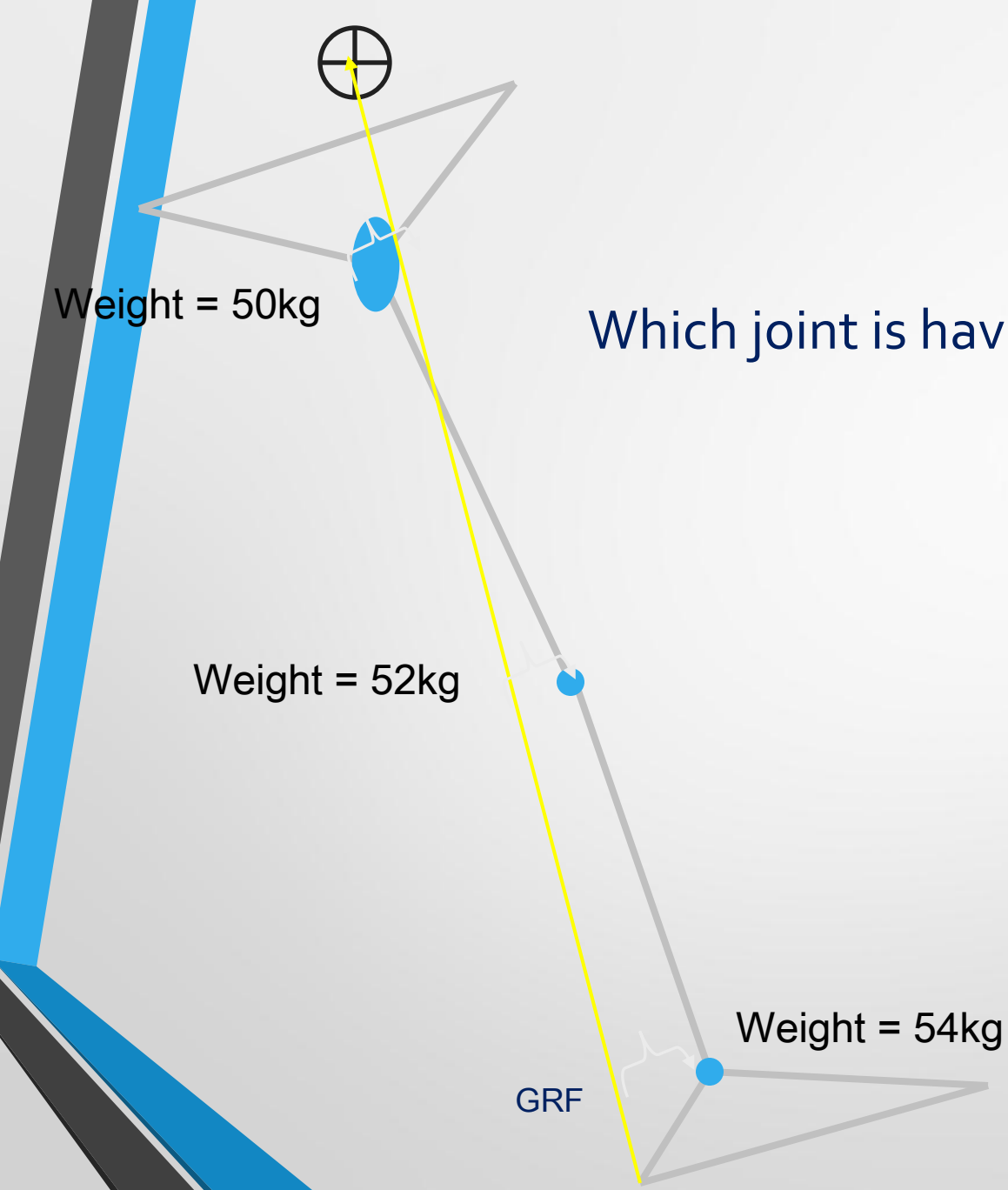






Moments

The greater lever arm, the greater moment is created.



Which joint is having the largest moment?

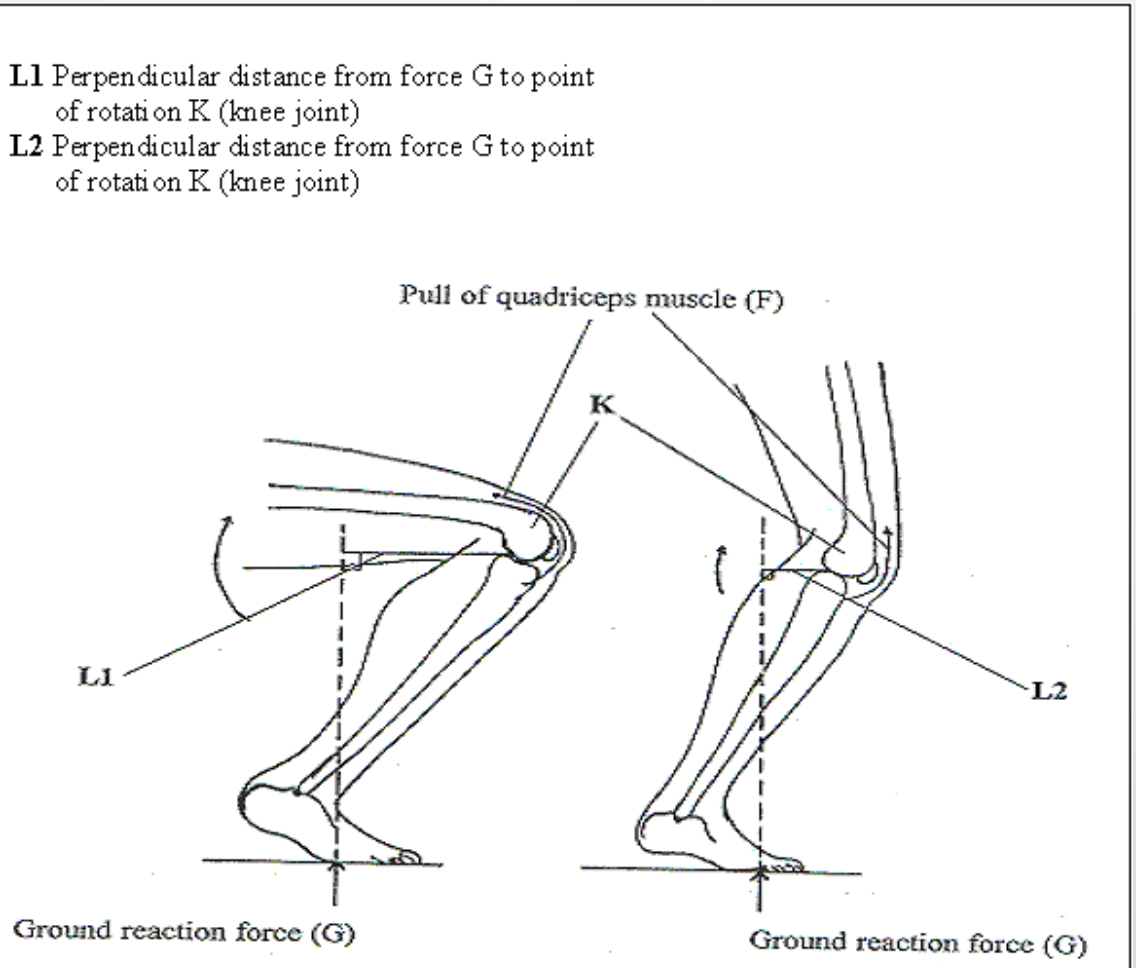
Rise from squatting

For Example:
Body weight
W=500N

L1: 30Cm
L2: 10 Cm

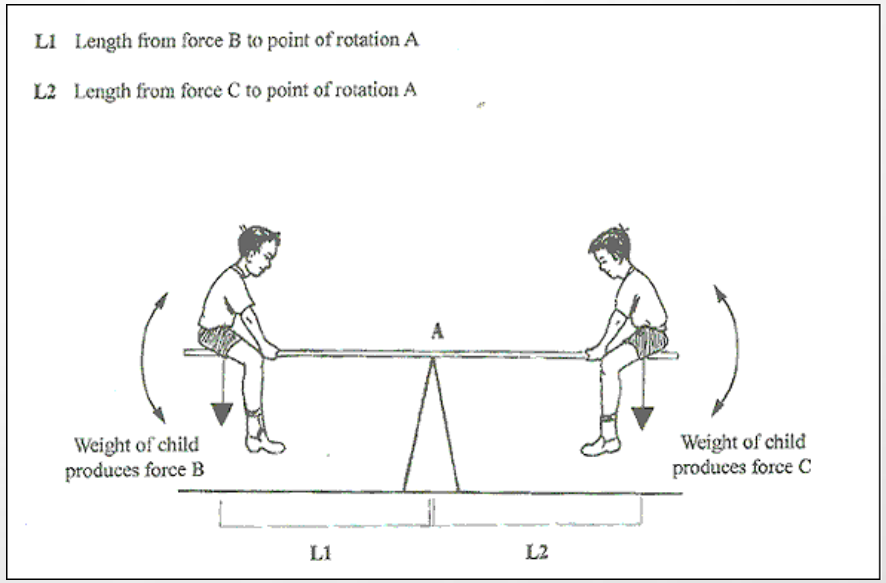
Distant from the knee axis to quadriceps
D = 2Cm

Find Force **(F)** of the quadriceps muscles to pull from squatting to standing



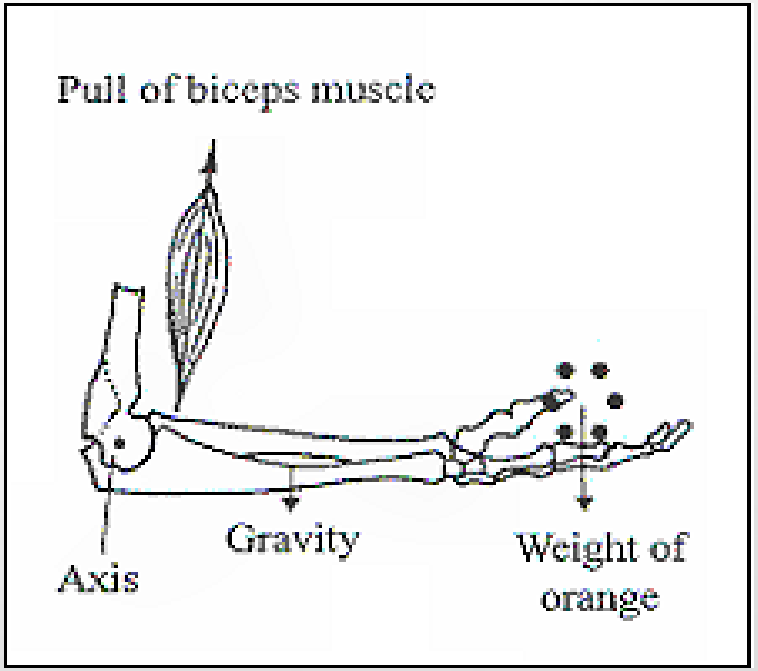
Parallel forces

- Forces are parallel when action lines are parallel
- Parallel forces acting on an axis can create bending or moment
- But if the parallel forces acting on different directions, the moment will turn to the directions of the big force and big lever arm



Parallel forces

- With human body, the parallel forces create rotation around anatomical axis (joint)
- Muscle and gravity are very important for providing the moment around the joint



Climbing upstairs

D1 Perpendicular distance from force G to point of rotation A

D2 Perpendicular distance from force T to point of rotation

A Ankle joint

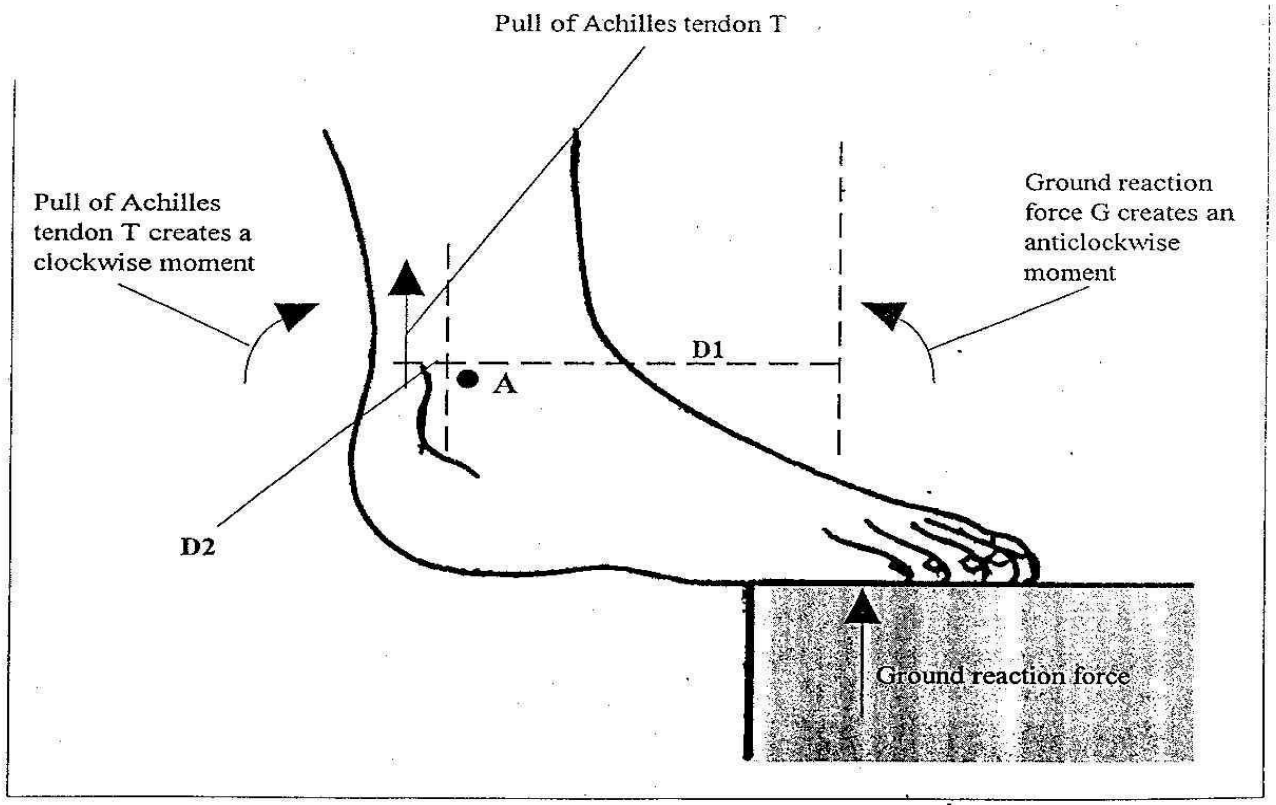
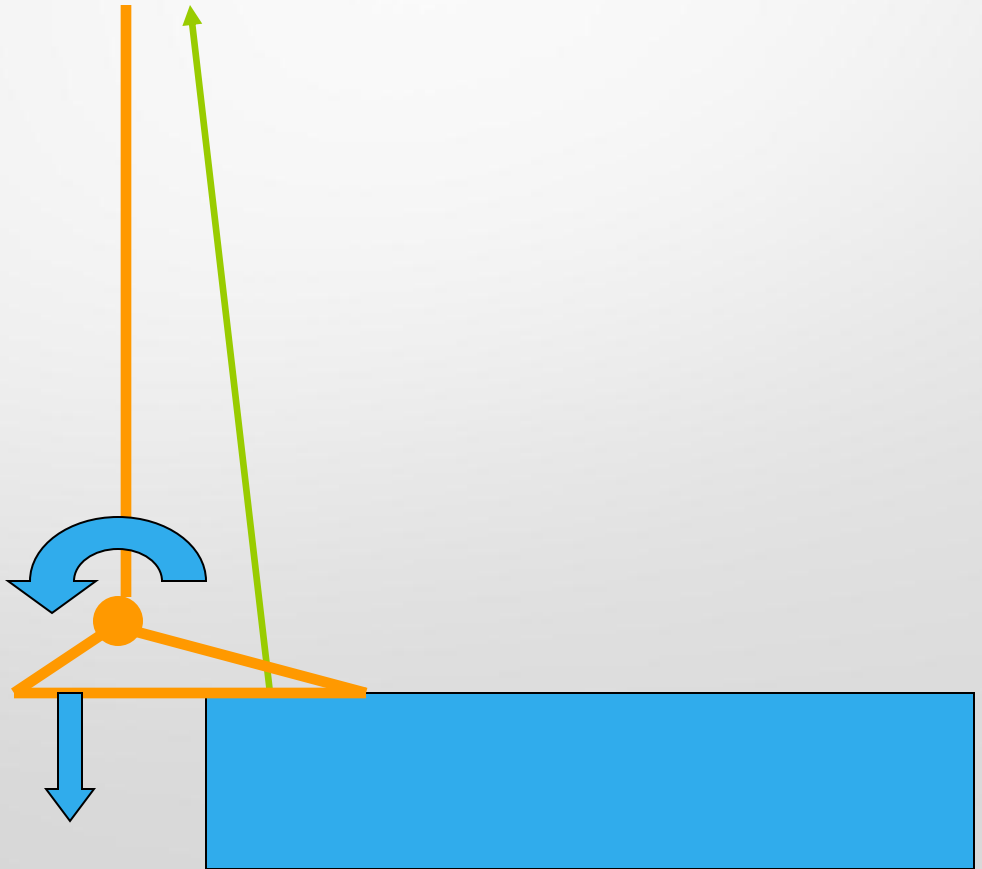


Fig 2.34 Parallel forces when climbing stairs

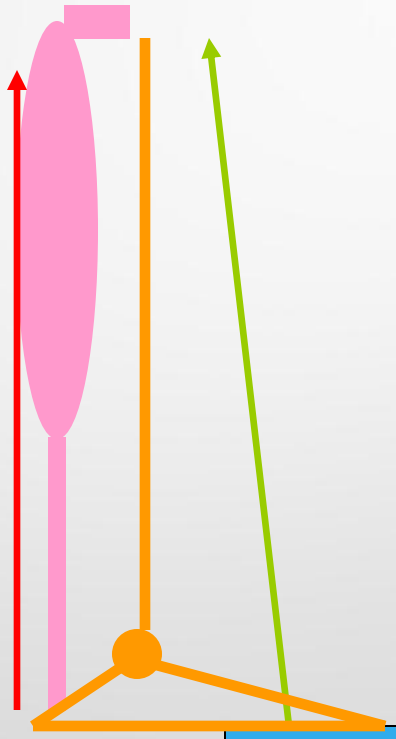
Moments

Ankle joint



Moments

Ankle joint



Moments

Why is this important for P&O?

If we wish to control movement, it is better to utilise longer lever arms.

Pressure and Moments

If we combine the two concepts

- lever arms
- pressure

- Best results if forces are spread over large areas, with long lever arms.

Pressure determines comfort

- If the prosthesis presses hard on the stump, patient will be uncomfortable.
- We can reduce pressure by increasing area of the stump which is in contact with the socket of the prosthesis
- Some parts of the stump will be more firm and other parts soft, and some parts can tolerate more pressure while other parts area sensitive.

Socket Pressures

- Sensitive areas cannot tolerate as much pressure as pressure tolerant areas
- Greater pressure could happen over the firm areas and bony areas

Goal:

- To distribute pressure and provide comfort

Socket Pressures

Solutions to distribute pressure:

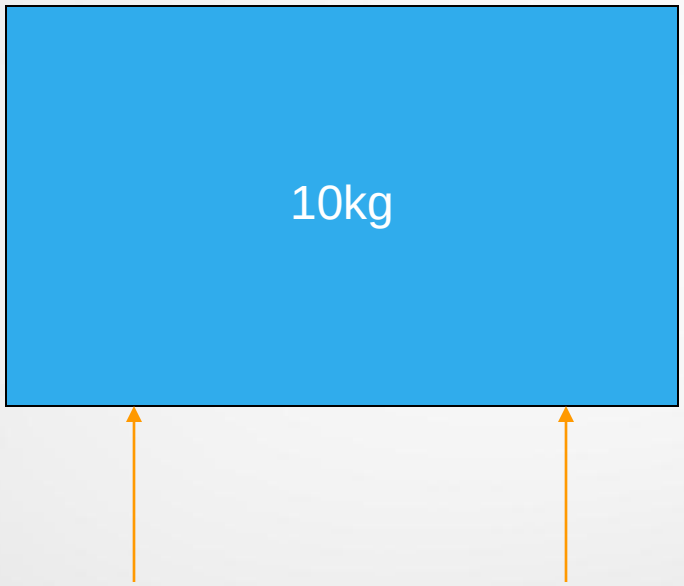
- Pressure tolerant areas (soft tissue areas): mold while casting and remove plaster during rectification
- Sensitive areas (bony areas): do not mold during casting and build up plaster during rectification

Sloped surfaces

Inside the prosthetic socket there are not many flat / horizontal areas.

How do sloped surfaces affect the force required?

Sloped surfaces

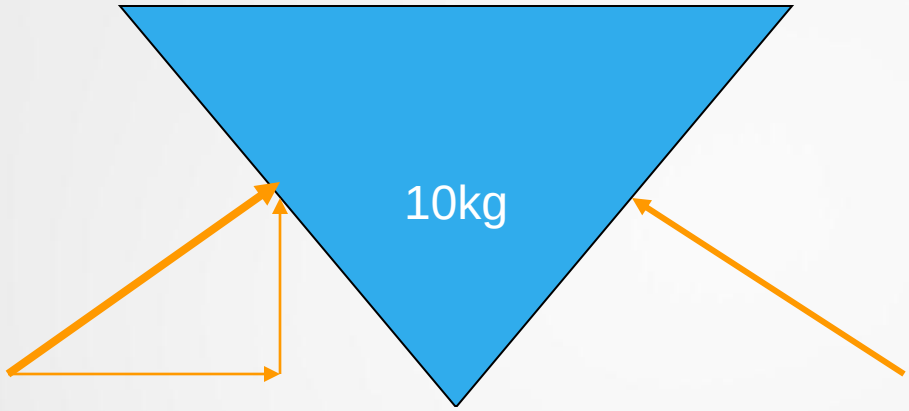


Ex.. If the force needed to hold this block up is equal and opposite to the downward force

(Downward force is 98.1N)

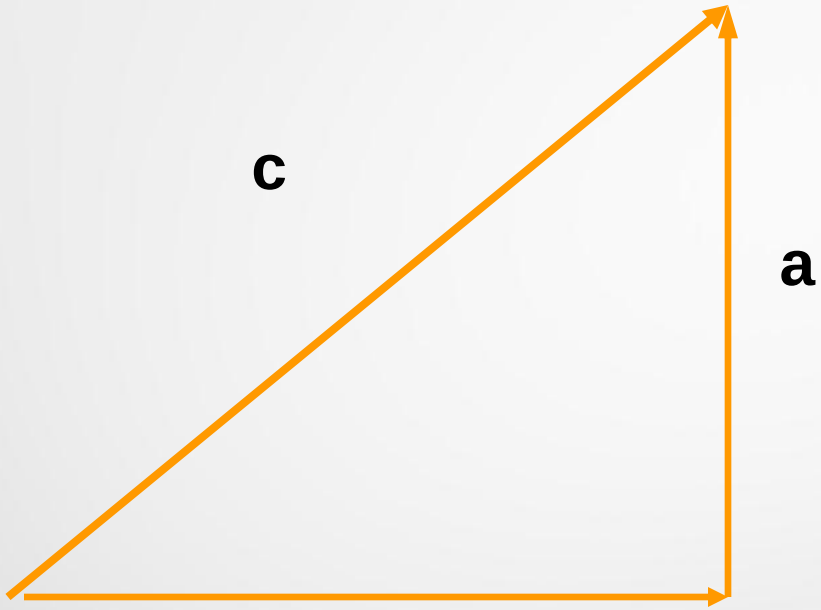
= each force must provide 49.05 N

Sloped Surfaces



- We know the vertical component of the force =49.5 N

Sloped surfaces



$$a^2 + b^2 = c^2$$

Sloped Surfaces

- The closer the force acts to the vertical, the horizontal component is reduced, the resultant force is reduced (i.e. when weight bearing surface is horizontal)

- The closer the force acts to the horizontal, the horizontal component is increased, therefore the resultant force is increased (i.e. if weight bearing surface tends towards vertical)

Sloped Surfaces

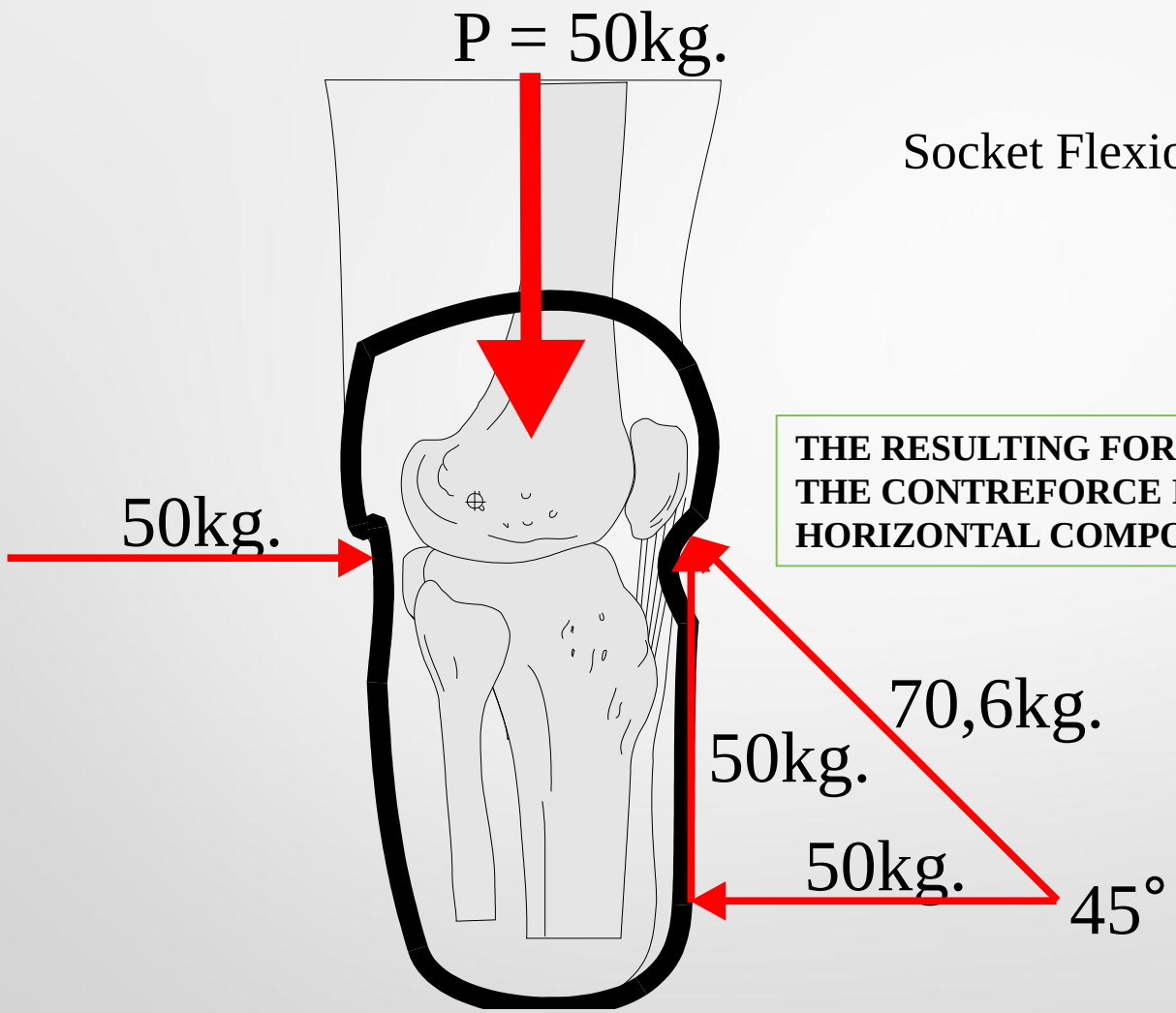
Why is this important in P&O?

Where possible we should use horizontal surfaces.

BUT this doesn't often happen in P&O

- mostly sloped → larger forces needed

- spread over large areas



Socket Flexion = 0°

THE RESULTING FORCE IS 70,6 kg.
THE CONTREFORCE IS EQUAL TO THE HORIZONTAL COMPONENT OF 50 kg.

Pressure Sensitive Areas

Some areas cannot take high pressure as

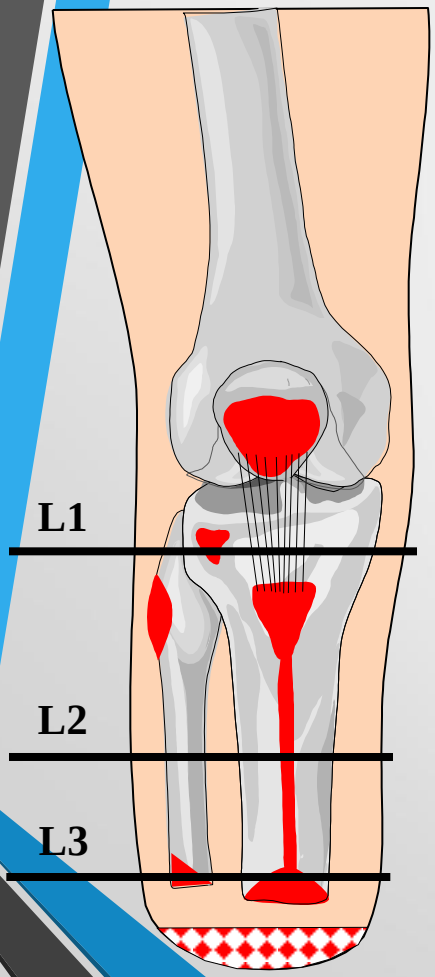
- Bony areas
  - Tibial Crest
  - Fibula Head
- Nerves
  - Peroneal nerve (just below fibula head)
- Scars

Pressure Tolerant Areas

- Some areas can take increased pressure as
  - Patella Tendon
  - Muscle bellies
    - Tibialis Anterior

Variation of the stump tissues

STUMP TISSUES WITH DIFFERENT DENSITY AND SENSIBILITY



SOFT TISSUES

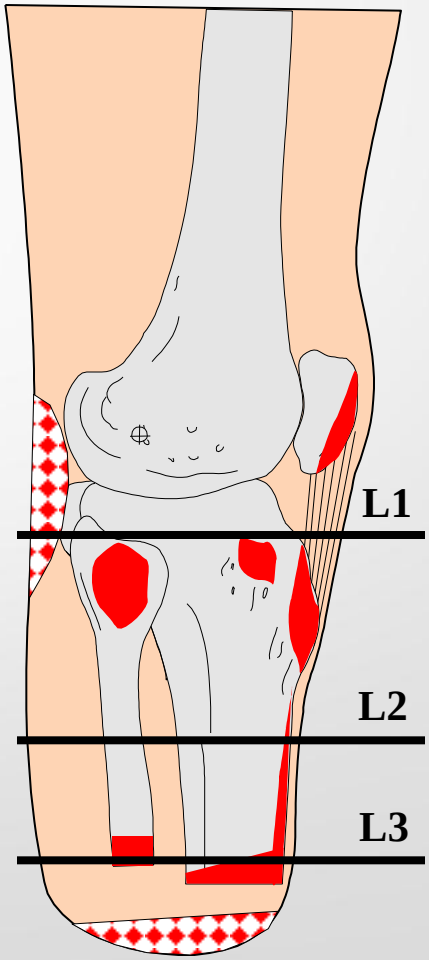
BONES

FIRM AND SENSIBLE AREAS

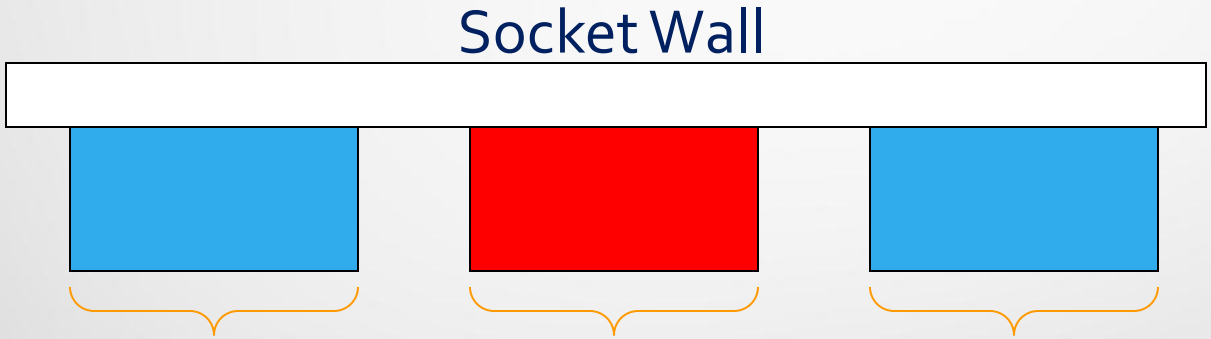
SOFT Y SENSIBLE

LEVELS 1, 2, 3

TO DISTRIBUTE THE LOAD ACCORDINGLY OVER THE AREAS WITH DIFFERENT DENSITY AND TOLERANCE TO THE PRESSURE IT IS NESESSARY TO IDENTIFY SENSIBLE AREAS.



Loading and Relieving



Pressure tolerant

(muscle)

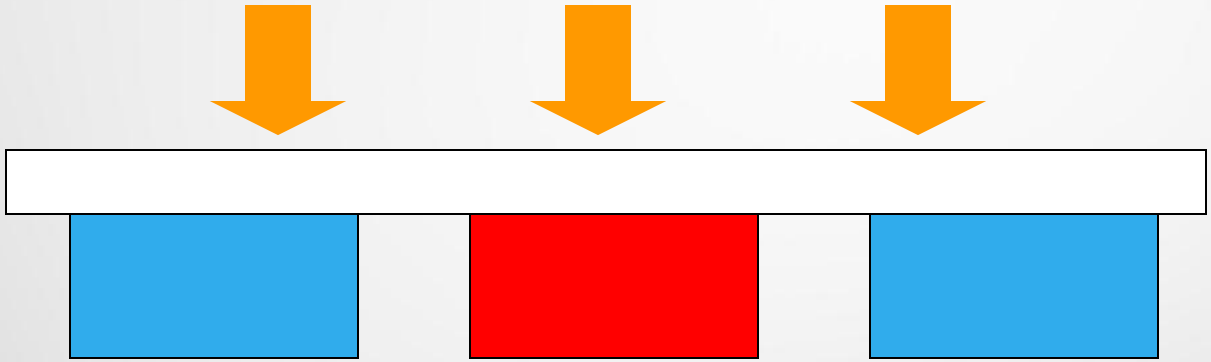
Pressure sensitive

(bone)

Pressure tolerant

(muscle)

Loading and Relieving



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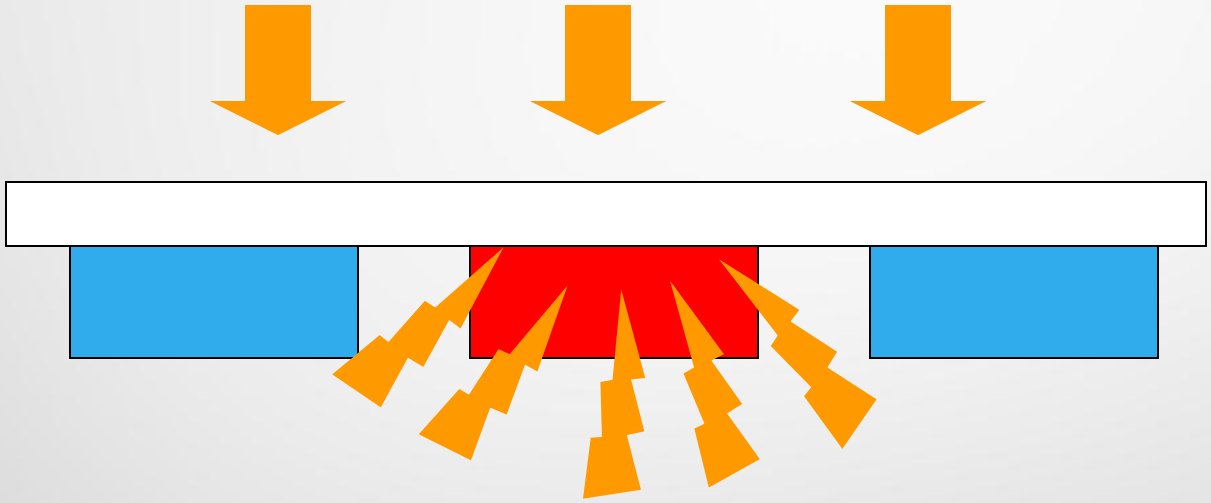


Muscles compress under pressure, and the bone takes the force

Loading and Relieving

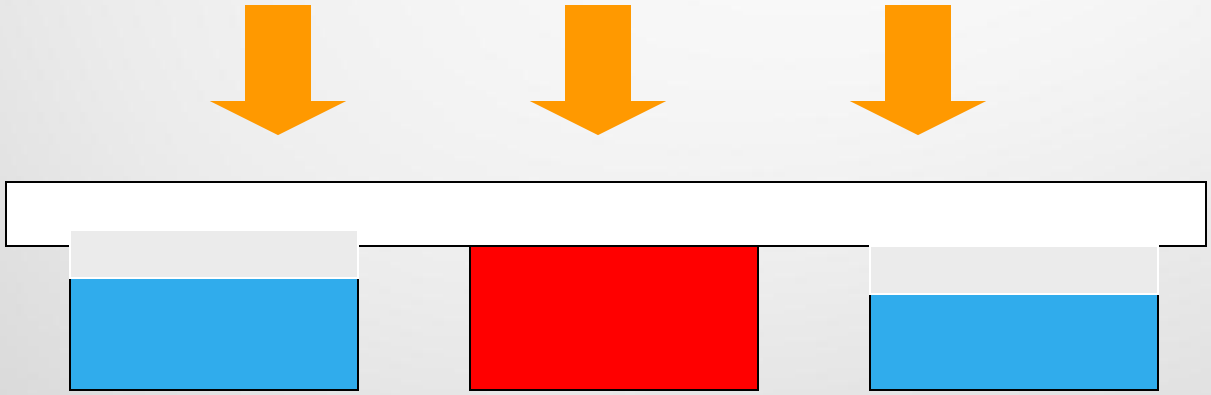
How can the socket be adjusted to avoid the problem of the bone taking the pressure?

Option 1

Load → Pressure Tolerant Areas

Loading and Relieving

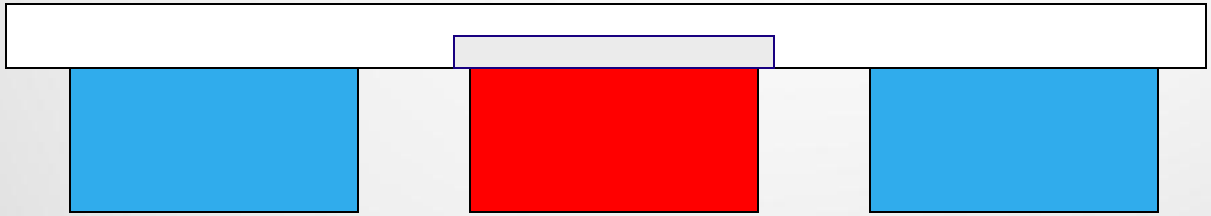
Muscles compress under pressure, but the bone takes no force.



Loading and Relieving

Option 2

Relieve → Pressure Sensitive Areas



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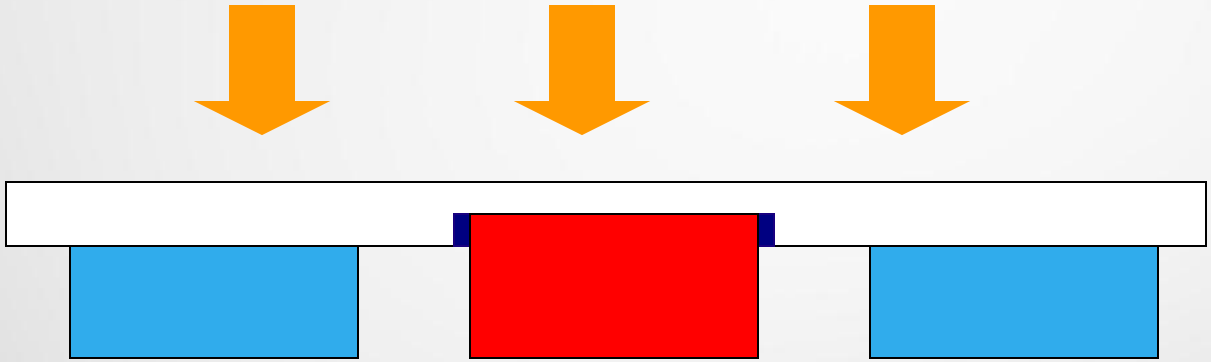


Muscles compress under pressure, but the bone takes no force.

Socket / Stump Interaction

In a prosthetic socket both options are used:

- Load → Pressure Tolerant Areas
- Relieve → Pressure Sensitive Areas

We can do it by using different shape or material on that area

= ALL Stump in contact

= some areas with pressure

= some areas without pressure

Socket / Stump Interface

Socket should be "Total Contact"

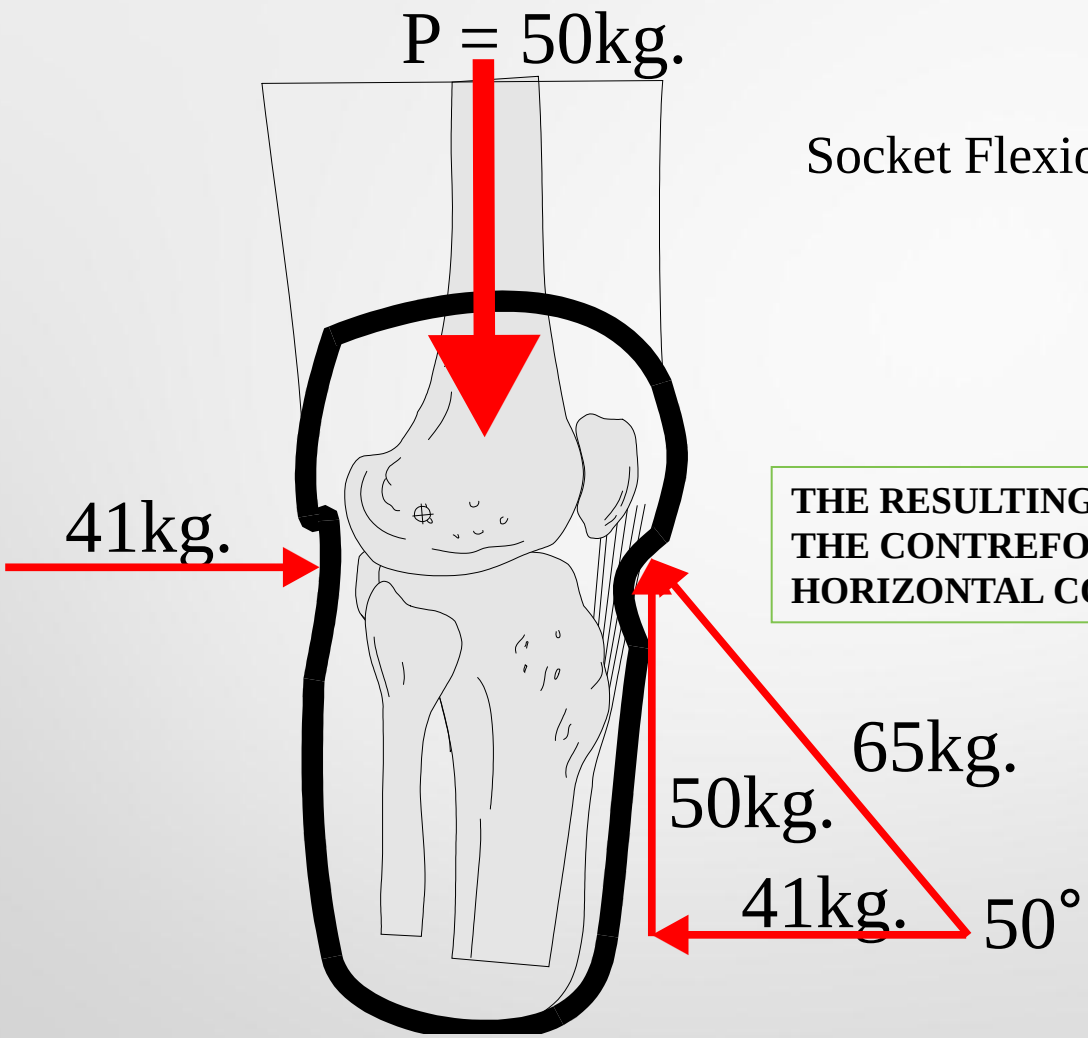
- all of the skin of the stump touches the socket.
  - Prevent oedema by increasing venous return
  - Reduce pressure by increasing surface area
  - Increased proprioception gives improved control

BUT not all tissues take the same amount of pressure.

Transtibial socket shape

We need to try to use horizontal surfaces

- Patellar tendon
- Slight flexion of socket
- Medial flare of tibia



Socket Flexion = 5°

THE RESULTING FORCE IS 65 kg.
THE CONTREFORCE IS EQUAL TO THE HORIZONTAL COMPONENT OF 41 kg.

Transtibial socket shape

- To maintain the position there needs to be an anterior directed counter force
  - Posterior wall , compression of popliteal muscles
  - Keep Posterior wall high

Transtibial socket shape

Loading of pressure tolerant areas

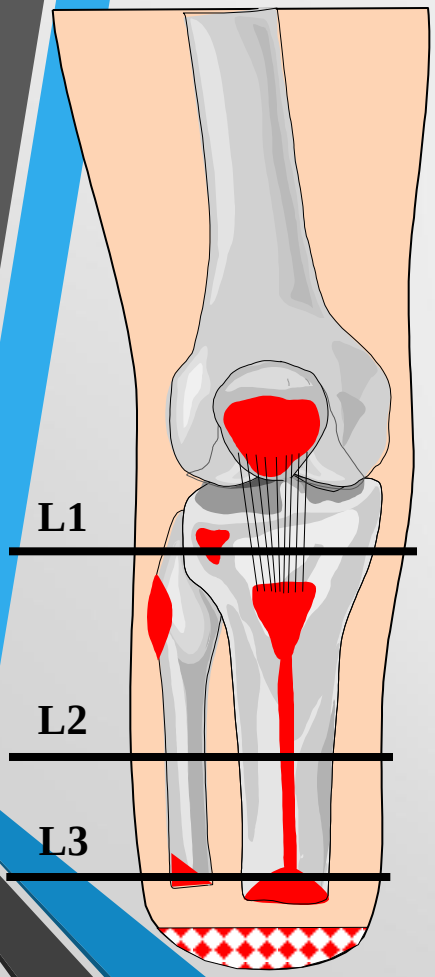
- Medial and lateral flares
- Popliteal area.
- Patellar tendon
- Gastrocnemius

Transtibial socket shape

- Offloading pressure sensitive areas
  - Tibial crest
  - Tibial tuberosity
  - Distal end
  - Fibular head

VARIATION OF THE STUMP TISSUES

STUMP TISSUES WITH DIFFERENT DENSITY AND SENSIBILITY



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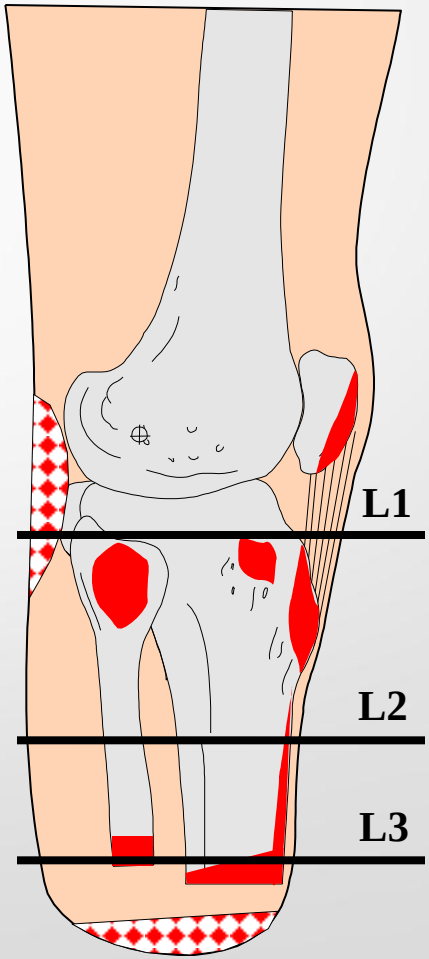

Summary of Terms and Definitions of some basic concepts of biomechanics

- Biomechanics
- Gravity
- Force
- Reaction force
- Ground Reaction Force
- Centre of gravity
- Stability
- Pressure
- Moment

Effect of weight bearing surfaces

- Horizontal and sloped surface

TT socket Biomechanics

- Total Contact
- Pressure Distribution concepts

ANY QUESTIONS?

Thank you very much