If you are viewing this course as a recorded course after the live webinar, you can use the scroll bar at the bottom of the player window to pause and navigate the course.

This handout is for reference only. It may not include content identical to the powerpoint. Any links included in the handout are current at the time of the live webinar, but are subject to change and may not be current at a later date.

Decoding and Understanding Transtibial Gait Biomechanics and Gait Deviations

Jared Howell, MS, CPO, FAAOP
Director, Baylor College of Medicine
Orthotics and Prosthetics Program

Foundational Objectives

- Articulate the key differences that make the amputated/prosthetic side unique when compared to the sound limb
- Develop an understanding of TT mechanical structure and alignable components.
- Learn about standard transtibial (TT) alignment parameters
- Develop baseline competence in identification of transtibial gait patterns.

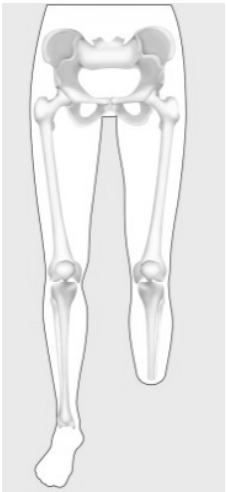
Baylor College of Medicine

So you have had a TT amputation, now what?

3 Underlying Mechanical Principles

Baylor College of Medicine

Anatomical Changes Following TT Amputation

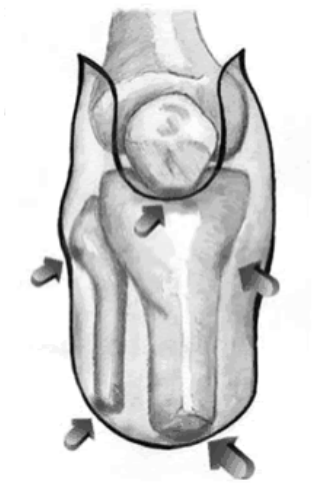


- Loss of Gastroc/Soleus Insertion
  - Reduces efficacy of gait
  - Reduces active knee extension
  - Poses risk to posterior compartment of the knee
- M/L Stability can be altered depending on mechanism of injury/cause of amputation

CONTINUED™

Baylor College of Medicine

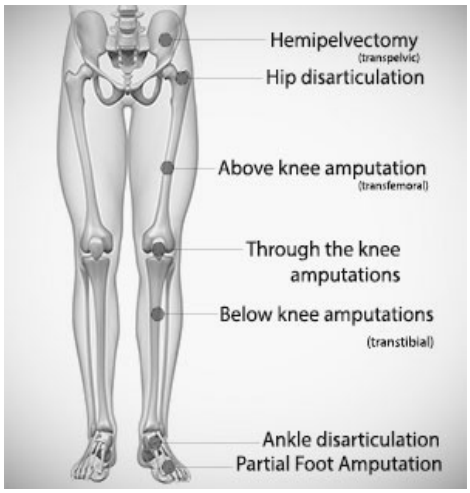
Soft Tissue Considerations



- In a socket all motion is transferred to the most proximal contact area
- The soft tissue of the residual limb takes the entire force of the body.
- The socket moves around the limb as a central axis.

Baylor College of Medicine

Joint Considerations



- The foot and the ankle are particularly helpful in the dissipation of force during stance phase.
- The loss of the foot and the ankle means that forces are transferred to the proximal joints in the limb and spine.

Baylor College of Medicine

Biomechanical goals

- 3 main biomechanical goals for TT prosthetics
  - Allow for maximum load bearing capacity on the limb
  - Promote knee flexion throughout stance phase
  - Provide optimal M/L stability throughout stance phase

Baylor College of Medicine

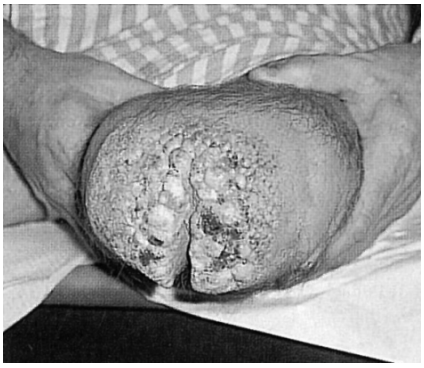
Maximum Limb Loading

- How do you increase the load bearing capacity of the limb?
  - total contact
  - Increase surface area that is loaded
  - load the pressure tolerant areas more
    - relieve pressure sensitive areas
  - flex socket to improve loading

Baylor College of Medicine

Maximum Limb Loading

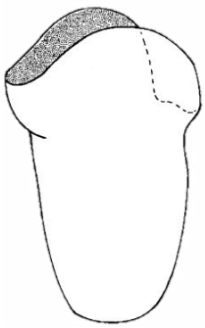
- Total Contact
  - Load as much surface area as possible
  - prevent Verrucous hyperplasia
  - Increase proprioception

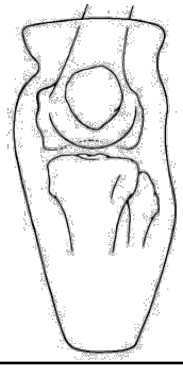


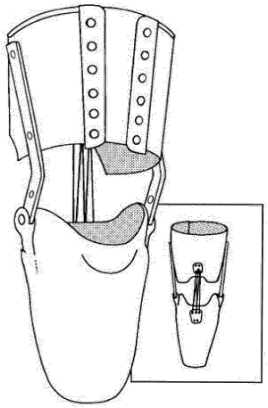
Baylor College of Medicine

Maximum Limb Loading

- Increase surface area
  - How can you do this?
  - Increase trim lines (the shorter the limb, the more proximal the trimlines
  - Joint and Corset



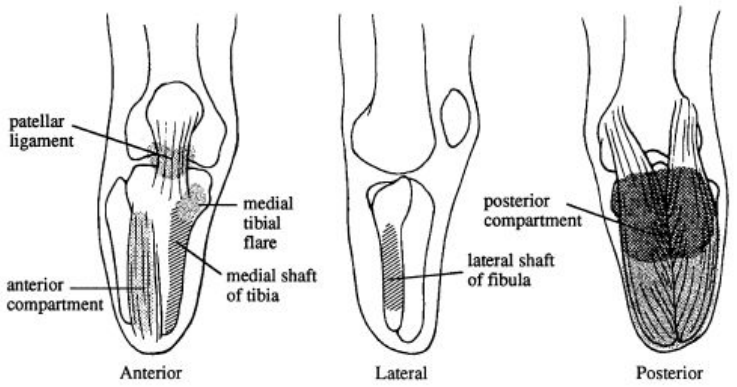




Baylor College of Medicine

Maximum Limb Loading

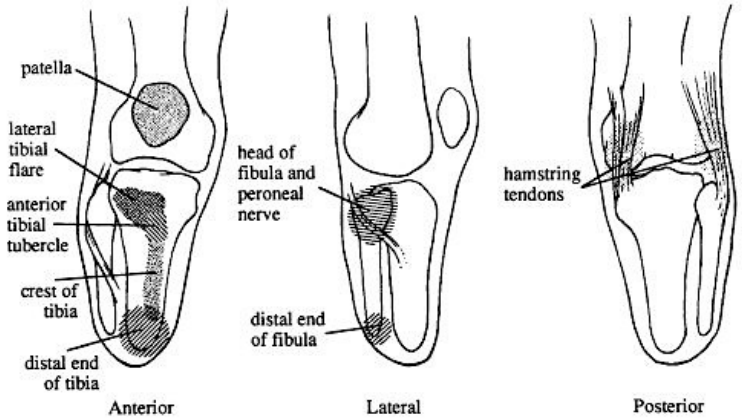
- Pressure Tolerant areas



Baylor College of Medicine

Maximum Limb Loading

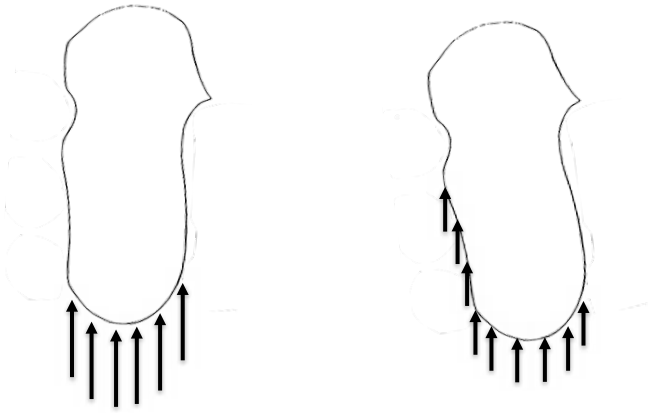
- Pressure intolerant areas



Baylor College of Medicine

Maximum Limb Loading

- Flex socket (3 reasons)
- Reason 1 is to maximize limb loading



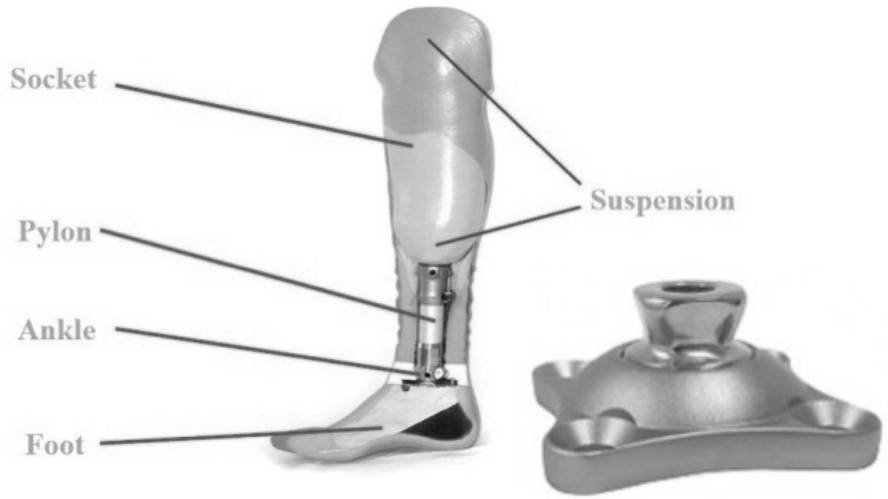
Baylor College of Medicine

Decoding Alignment

- The spatial relation of the ground contact(foot) to articulating parts(knees/ankles), to the interaction with the body (socket)
- Bench Alignment
- Static alignment
- Dynamic Alignment

Baylor College of Medicine

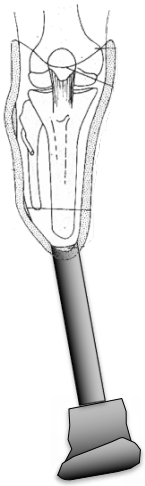
Alignable Components



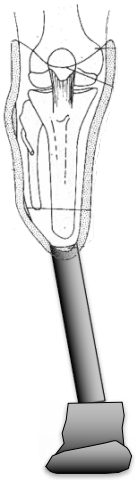
Baylor College of Medicine

How is this alignment changed?

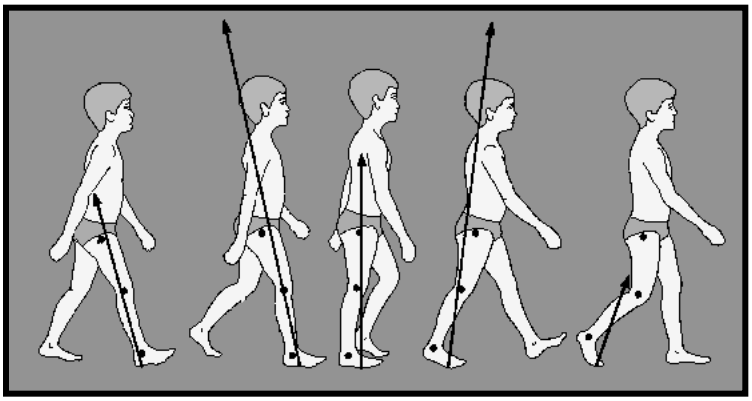
One set of Screws = angular change



Top and bottom screws = translational change

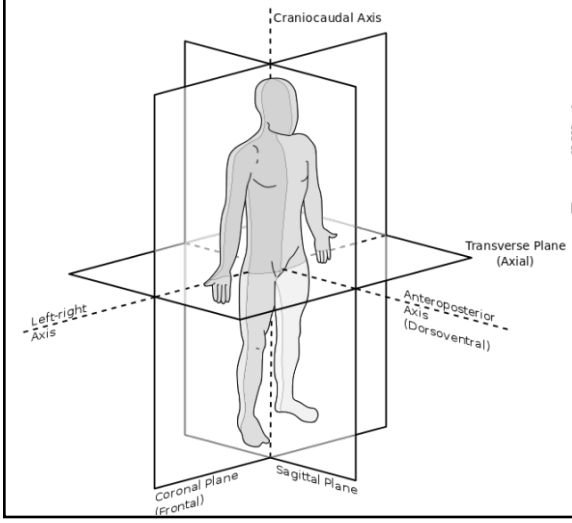


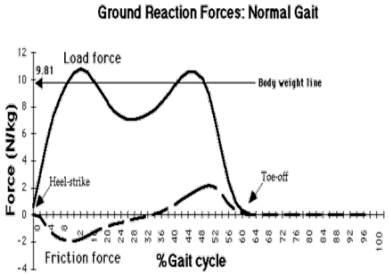
Prosthetic gait is 100% dependent on position of the ground reaction force in reference to the joints of the body

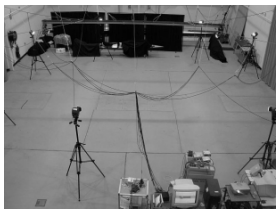


Baylor College of Medicine

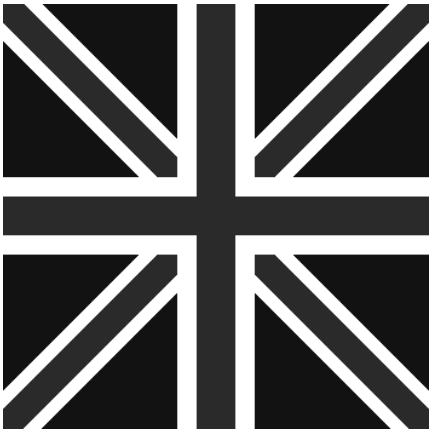
Visual Gait Analysis/Observation







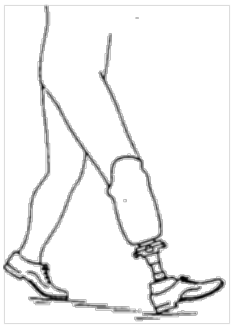
Normal vs. Symmetrical

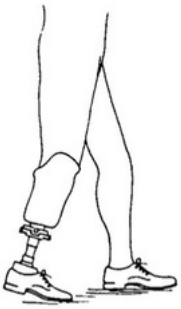


Baylor College of Medicine

Sagittal Control

- Reason 2 and 3 deal with sagittal control
  - #2 encourage knee flexion moment at heel strike
  - #3 discourage knee extension moment at terminal stance





Baylor College of Medicine

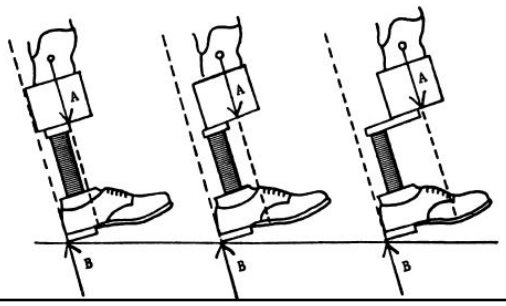
Sagittal Control

- 3 ways to encourage knee flexion
  - socket flexion
  - A-P placement of socket relative to the foot
  - Heel/toe durometer/flexibility

Baylor College of Medicine

Sagittal Control

- A-P placement of socket relative to the foot
  - How does this promote knee flexion at IC?
  - How does this discourage an extension moment at terminal stance?



Baylor College of Medicine

Sagittal Control

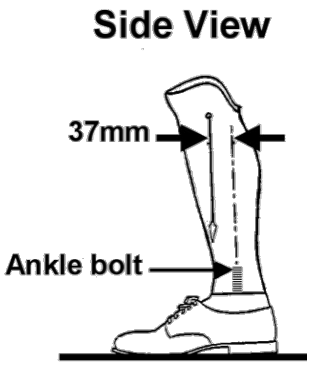
- A-P placement of socket relative to the foot

For a SACH foot

  - Textbook bench alignment is the foot bolt to be 37mm posterior to midline of the socket
  - final range is 18-65mm

For a Dynamic foot

  - Socket midline is set up typically between the first and second third of the foot. or per manufacturer's recommendation



Baylor College of Medicine

Test Your Knowledge

- Heel/Toe durometer or flexibility
  - Heel stiffness or durometer acts as the dorsiflexors. How?
  - What does the heel do?
    - Shock absorption
    - Hip and knee extensors control this shock absorption (greater activity required)
  - If it does not absorb shock, where does it get translated?
    - into abrupt knee flexion

Baylor College of Medicine

Sagittal Control

- a cushioned heel will reach foot flat sooner, progressing the GRF anterior to the knee quicker
  - creating which moment?

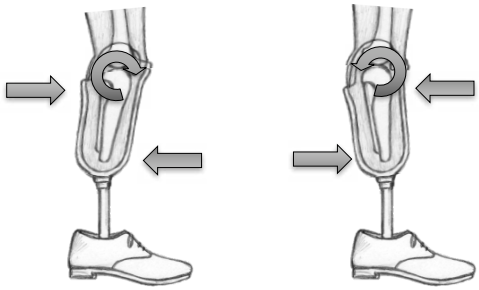
    flexion, or extensions (circle one)
- The shorter the limb, the more cushioned heel, the less external knee flexion moment
- A stiff heel will create a more posterior GRF
  - creating which moment?

    flexion, or extensions (circle one)
- A stiff heel may also present as a rapid external rotation of the foot

Baylor College of Medicine

Sagittal Control

- Socket flexion/extension
  - During stance, what moment acting against the limb does a flexed socket create?
  - What moment acting against the limb does an extended socket create?



Baylor College of Medicine

The Affect of Poor Alignment

- Poor Alignment is just as detrimental to the health of the limb as a poor fitting socket
- Any open wounds need to be treated quickly and efficiently and should involve all members of the health care team

Transtibial Gait

CONTINUED™

Baylor College of Medicine

Sagittal Control

- Heel stiffness

Baylor College of Medicine

Sagittal Control

- Heel/Toe durometer or flexibility
  - Toe stiffness acts as what muscles?
  - too stiff creates what moment?
  - too soft creates what moment?

Baylor College of Medicine

Sagittal Control

- Early Drop off and excessive dorsiflexion

Baylor College of Medicine

Sagittal Control

- Early Drop off
  - Rapid loss off support in late stance
  - what excessive moment is being experienced?
  - Where will they experience discomfort?
  - They may feel this discomfort and not show physical signs of early drop-off
  - name 4 possible causes:

Baylor College of Medicine

Sagittal Control

- Delayed progression/Halted gait/foot slap cushioned heel

Baylor College of Medicine

Sagittal Control

- Delayed progression
  - Can create hyperextension
  - requires much more energy
  - Name 4 possible causes

Baylor College of Medicine

Sagittal Control

- Hyperextension

Baylor College of Medicine

Sagittal Control

Flexion Moment

- Socket is anterior to foot
- socket too flexed
- Toe lever is too soft
- Heel is too stiff

Extension Moment

- Socket is posterior
- Socket is too extended
- Toe lever is too rigid
- Heel is too soft

Baylor College of Medicine

Sagittal Control Alignment Review

- Bench alignment
  - 5 flexion in socket
  - center of weight (sagittal midpoint at MTP) falls at 37mm anterior to SACH bolt, or between the first and second thirds for a dynamic foot
  - foot 5-7 degrees external rotation
- Static Alignment
  - Weight centered over foot. The patient does not feel like they are falling backwards or forwards
- Dynamic alignment
  - smooth rollover
  - no early drop-off or delayed progression

Baylor College of Medicine

Medial-Lateral Stability

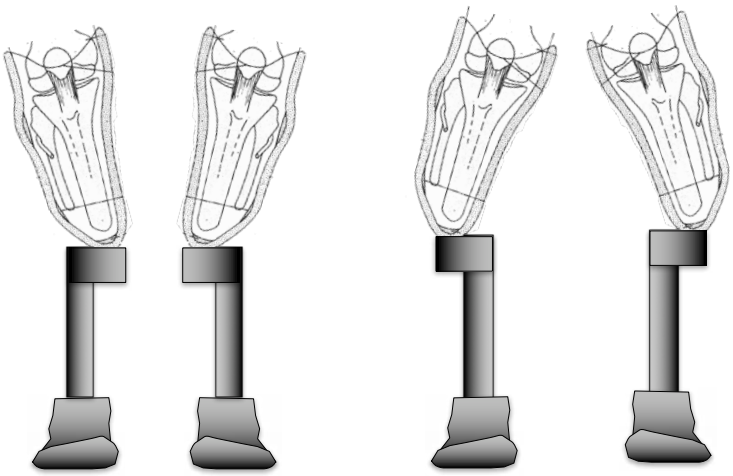
- Promote M/L stability during stance
  - create a varus moment at the knee for many reasons
    - mimics NHG and therefore:
      - Narrows base of support
      - Lowers energy expenditure (determinant of gait)
    - Loads pressure tolerant areas of the limb
    - lateral collateral ligament is less prone to injury
      - More flexible and stronger

Baylor College of Medicine

Medial Lateral Alignment

Socket Adduction in closed chain

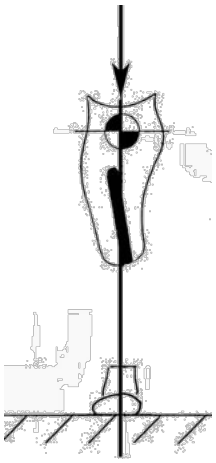
Socket Abduction in closed chain



Baylor College of Medicine

Medial-Lateral Stability

- Proper Abduction of the socket
  - Bench Alignment: depends on the limb. based on line obtained during casting
  - Mimics NHG
  - provides varus alignment
  - Not always ideal (Genu Valgum vs Genu Varum)

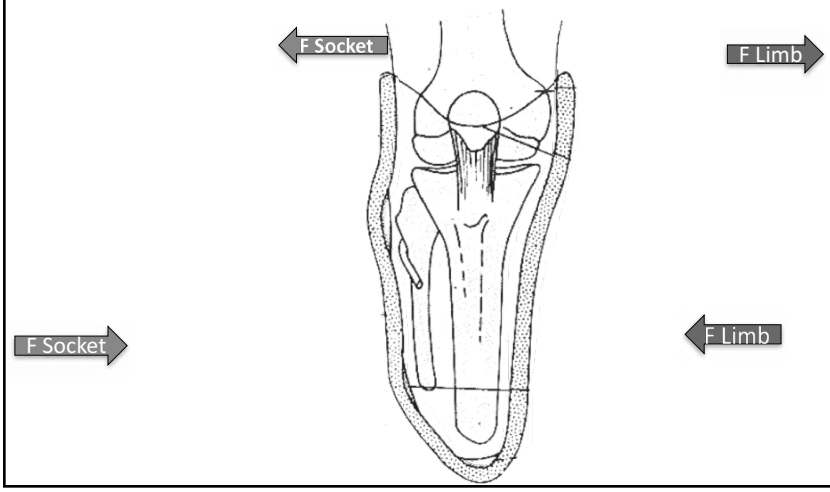


- Lets look at outset/inset

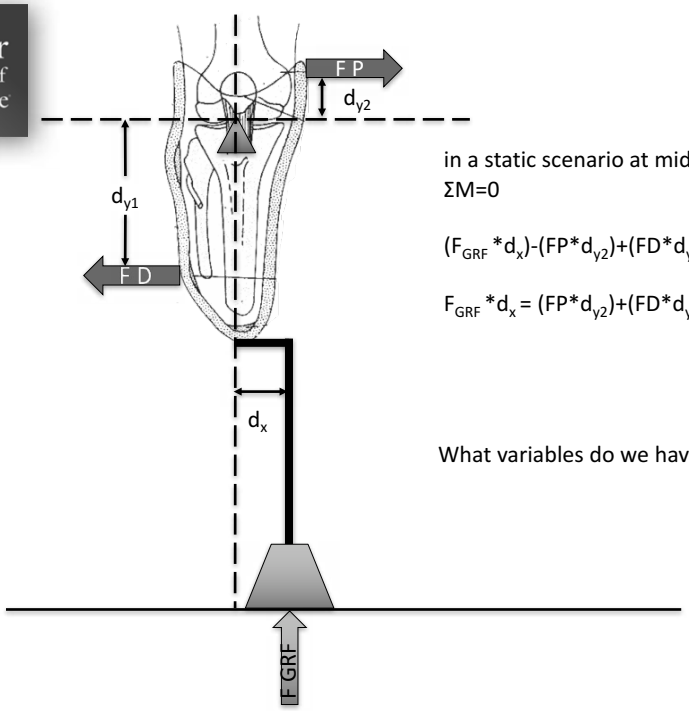
Baylor College of Medicine

Medial Lateral Stability

- Forces that are applied



Baylor College of Medicine

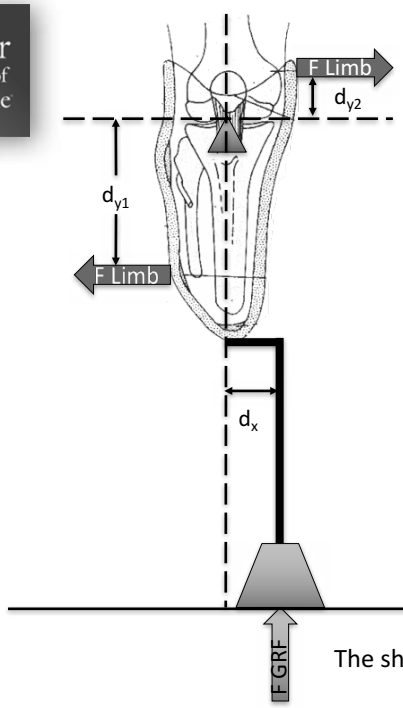


in a static scenario at midstance:
$\Sigma M=0$

$(F_{GRF} * d_x)-(FP*d_{y2})+(FD*d_{y1})=0$

$F_{GRF} * d_x = (FP*d_{y2})+(FD*d_{y1})$

What variables do we have control of?



Which force is greater, prox or dist?

If the proximal force is too great, what variables can we change?

As d_{y1} decreases what happens to the distal force?

How can you fix this problem?

The shorter the limb, the less the foot is inset

Medial Lateral Stability

Varus Moment

- Inset foot
- Socket abduction
- Associated pressures
  - Proximal Medial
  - Distal Lateral

Valgus Moment

- Outset foot
- Socket adduction
- Associated pressures
  - Proximal Lateral
  - Distal Medial

Baylor College of Medicine

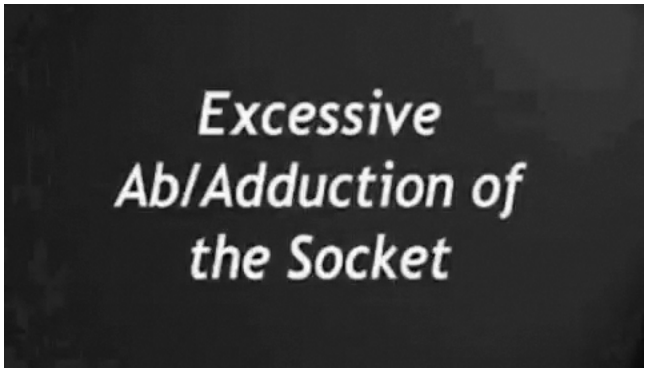
Medial Lateral Stability

- Excessive Valgus/Varus

Baylor College of Medicine

Medial Lateral Stability

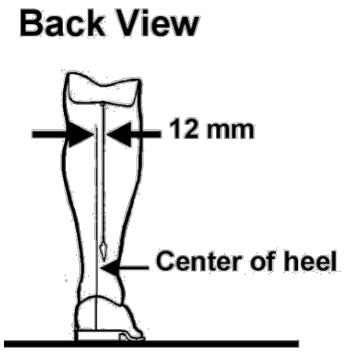
- Excessive Abduction/Adduction



Baylor College of Medicine

M/L Alignment Review

- Bench Alignment:
  - 12mm inset of midfoot to midline at MPT
  - adduction depends on the limb. based on line obtained during casting



Baylor College of Medicine

Lets review

- List three reasons why we flex the socket?
- With an excessive varus moment, where are the pressures experienced?
- With an excessive valgus moment, where are the pressures experienced?
- With an excessive flexion moment, where are the pressures experienced?
- With an excessive extension moment, where are the pressures experienced?

Baylor College of Medicine

the end.

Questions?