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Foundational Objectives

- Articulate at least three basic biomechanics of Transfemoral (TF) amputations.
- Identify at least three common gait deviations affecting individuals with a TF amputation.
- Explain the differences between the underlying causes of at least 3 deviations.
- Identify 1-2 successful treatment options for each gait deviation.
- Explain the involvement and role of each member of the team in optimizing gait of individuals with amputation.
- Describe at least 3 ways that biomechanical variations can be affected through prosthetic treatment.
So you have had a TF amputation, now what?

3 Underlying Mechanical Principles

Anatomical Changes Following TF Amputation

- Amputation level has significant influence on remaining muscle function, knee function and stability
- TFL/IT
- Adductor Magnus
- Knee Extensors/Quads
- Knee Flexors-Hamstrings
Soft Tissue Considerations

- This is the most difficult of all amputation levels to fit.
- You have significant soft tissue surrounding a single bone.
- One of the only major prosthesis to bear weight on segment proximal to amputation level.

Joint Considerations

- Loss of dozens of joints makes force dissipation much more complicated.
- Muscles used to stabilize and operate the prosthetic knee joint are different from those used prior to amputation.
Biomechanical goals

• Coronal Plane
  – Provide ML stability of the pelvis during midstance on the prosthetic side
  – Conserve energy by minimizing excessive lateral displacement

• Sagittal Plane
  – Provide anterior-posterior stability of the prosthetic knee joint between heel strike and heel off
  – Permit the prosthetic wearer to take a normal step with the non-amputated side

Transfemoral Biomechanics

Coronal Plane Objectives

Provide M-L Stability of the Pelvis at Mid-stance on the Prosthetic Side
(You must stabilize the femur)
Conserve Energy by Minimizing Lateral Displacement of the Center of Gravity During Gait
Provide M-L Stability of the Pelvis at Midstance on the Prosthetic Side

• In NHL, forces controlled by abductors

150# person * 3" lever = Muscle force *2" lever

Muscle force = 1.5 * body weight

Minimize excessive ML movement

• Narrow base of support

• May need to compromise energy consumption for comfort
Things that influence ML stability

1. Ischial weight bearing
2. Creating a Varus Moment at the Hip
   1. M/L position of the foot.
   2. Adduction of the lateral wall of the socket
   3. Proper contour of the lateral wall
3. High medial wall
4. Proper dimensions of the socket
5. Addition of Belt/band/hip joint

Ischial weight bearing

- Displaces fulcrum (supporting point) medially
- Thereby reduces magnitude of the moment
Varus Moment at the hip

- Pelvis tilts toward unsupported side
- Hip abductors fire to balance moment
- Femur displaces laterally

Proper position of the foot

- Static alignment initial position:

  Plumb bob from the ischial seat will bisect the heel of the shoe
Adduction of lateral wall

- Re-establishes the normal angulation of the femur (6-7 degrees)
- Puts the abductors on stretch—better mechanical advantage for Gluteus Medius

Proper contouring of lateral wall

- Allows for even distribution of force over the lateral aspect of the residual limb
- Socket relief must be provided for the lateral distal end of the femur (and greater trochanter)
Additional Advantages of Lateral Contour

- Lateral Wall Contour Doesn’t Match
- Localized Distal Pressure

Provide high medial wall

- Needs to be high enough to apply counter pressure to maintain good contact between femur and lateral wall
  - Counter Pressure to Lateral Wall
  - 2-Point Pressure
  - Restrict M-L Movement
  - Take Pressure from Ischium
  - Subischial Triangle
Proper socket dimension

- Too large an ML will reduce effectiveness of lateral and medial walls to stabilize femur
- A-P Too Large
  - Ischium is displaced anteriorly
  - Ramal Contact
  - Gait Deviation, “Antalgic Gait”
    - Lateral Trunk Bending
    - Abducted Gait
- Lateral A-P is Significant
  - Ischial Containment
  - Tight Antero-Lateral Wall

Silesian belt or Hip Joint

- When hip abductors are weak
- When working with someone with a short residual limb
- High wall not enough: gaps away
- Max stability through hip joint and pelvic band
Sagittal Plane Objectives

- Provide A-P Stability of the Prosthetic Knee Joint Between Heel Strike And Heel Off
- Permit the Amputee to Take a Normal Stride Forward With the Non-amputated Limb

Extension: Not a “normal” moment

- Ground reaction force must remain anterior to the knee joint from heel strike to heel off on the prosthetic side
- Through
  - Knee Alignment
  - Foot Alignment/ Selection
  - Components
  - Voluntary control (hip extensors)
Things that influence AP stability

1. Socket, Knee, and Foot Alignment in Sagittal Plane
2. Foot Selection
   1. Stiffness of Heel
   2. Length and Stiffness of Keel
3. Knee Selection-Inherent Stability
4. Symmetric Step Lengths

Provide A-P Stability of the Prosthetic Knee Joint Between Heel Strike And Heel Off

- Alignment of socket knee and ankle
- Heel Durometer
- Keel Resistance
**TF Alignment**

- Linear knee position (sagittal plane)
- Determines Knee stability and efficiency

**TF Alignment w/ I.C.**

- Place appropriate flexion and adduction in the socket
- Bisect socket (at Ischial level)
- *Weight line* should fall 10-15mm anterior to single-axis knee joint
Heel Durometer and keel resistance are critical to knee stability in the sagittal plane

- The softer the heel, the more stable the knee
- The stiffer the keel, the more stable the knee

Heel Stiffness

- Acts as dorsiflexors
- Soft heel reaches foot flat sooner and moves gfr ahead quickly
- Too stiff a heel cushion (or _______ bumper) may cause instability
Heel Stiffness

- Softer Heel more Stable
  - Throws Reaction Line Anterior
- Too Stiff; Lateral Rotation
- More Proximal Amputation Softer the Heel
- Transfemoral Require Cushioning
  - No Shock Attenuation from Knee

Keel Design & Stiffness

- Need Anterior Support
  - Inadequate resistance to dorsiflexion between midstance and heel off may cause ground reaction force to pass behind the knee center
- Drop off is Loss of Support
  - Potentially Dangerous
  - Knee Center Moves Anterior
    - Knee Buckles
- Too Stiff, Sideward Gait
- Manufacturers Alignment
Knee Components

• Type of knee also affects AP stability
• Current research shows microprocessor knees as being by far the most stable

Knee Design

- Least Stable
- More Voluntary Control
- Most Stable
- Less Voluntary Control

- Outside Locking Knee
- Single Axis Knee
- Braking Knee
- Polycentric Knee
- Manual Locking Knee

*Microprocessor Controlled
Symmetric Step Lengths

Permit a normal sound side step

- Flexion contractures are incredibly common in individuals with TF amputation
- If a flexion contracture is present align to 5 degrees + flexion contracture
- Secondary benefit, place extensors on stretch
Long residual limbs

- To bench align with stable knee, very uncosmetic

With significant contractures

- Can compromise function and cosmesis
- Pick a very stable knee
- Use a single axis foot
Gait Deviation
Transfemoral Amputee

Visual Gait Analysis/Observation
Normal vs. Symmetrical

Gait Analysis/Terminology

- Initial Contact = Heel Strike
- Loading Response = Foot Flat
- Midstance = Midstance
- Terminal Stance = Heel Off
- Pre-Swing = Toe off
  - Initial Swing
  - Mid Swing
  - Terminal Swing
    - Same
Prosthetic gait is 100% dependent on position of the ground reaction force in reference to the joints of the body.

Normal Human Gait
Transfemoral Gait Deviations

- Abducted Gait
- Circumduction
- Unequal Step lengths
- Lateral trunk bending
- Excessive Heel Rise (Swing Phase)
  - Lateral Medial/Whips
  - Premature flexion of knee

Abducted Gait
Circumduction

Unequal Step Lengths
Medial Whip

Premature Knee Flexion/Instability
Gait Training Video
Advanced Gait Training

Ignore the product piece, but look for fundamentals of TF gait training. Including Center of Mass and Pelvic Rotation Training

Bob Galley: Rheo Gait Training Video

http://www.youtube.com/watch?v=HZOFaukYoT4

Thank You
Questions?