Gait
Trans-Tibial Amputee

M. Jason Highsmith, PT, DPT, CP, FAAOP
University of South Florida
College of Medicine
School of Physical Therapy & Rehabilitation Sciences
"Demonstration Project on Prosthetics & Orthotics"

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Objectives

After reviewing this material, the reader will be able to:

- Describe favorable/typical trans-tibial prosthetic alignment
- Identify trans-tibial gait deviations in all 3 anatomic planes
- Discuss the effects of trans-tibial gait deviations on the user
- Identify prosthetic and amputee causes of deviations

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Trans-Tibial Gait

- Prognosis
- Demographics
- Problem
- Foot Function During Gait
- Biomechanics
  - Sagittal Plane
  - Frontal Plane
  - Transverse Plane
- Proper Alignment
  - Frontal View
  - Sagittal View
- Gait Deviations
  - Extension Moment
  - Flexion Moment
  - Varus Moment
  - Valgus Moment
  - Transverse Plane Problems

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Prognosis

- Trans-tibial prosthesis users
  - In the absence of severe comorbidities
- Tend to have prognoses favoring pre-morbid activity
- It is reasonable to expect return to most activities

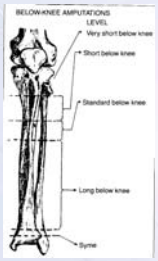
Courtesy of Otto Bock Health Care

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Demographics

When toe amputation is not considered:

- Trans-tibial amputation is most represented level of limb loss:
  - 45% trans-tibial followed closely by
  - 40% trans-femoral then steep drop to
  - <10% below elbow (UE) at 3rd most represented level



Northwestern University Prosthetic Orthotic Ctr

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Problem

With trans-tibial amputation:

- The leg is not lost
  - Some portion of the leg is lost but
  - most muscles acting on the knee are present
- The **foot** is lost

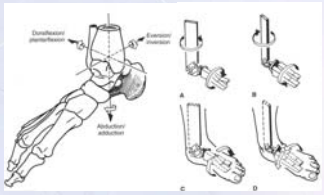
Netter

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Functions of the Foot During Gait:

Sensory feedback about

- Surface
  - Level/ slope
  - Compliance
  - Texture
- Body Information
  - Position
  - Ground reaction line
- Shock attenuation
  - through numerous joints
  - Intrinsic muscles
  - Extrinsic muscles
  - Ligaments
- Propulsion
  - Winlass mechanism
  - Muscular tension & contraction



Nordin and Frankel

A prosthetic foot serves to mechanically replicate these functions

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Biomechanics: The Basics

There are 5 phases of Stance

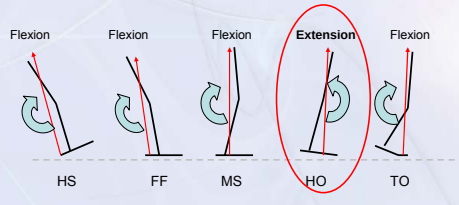
1. Initial Contact/Heel Strike (HS)
2. Loading Response/Foot Flat (FF)
3. Mid-stance (MS)
4. Terminal Stance/ Heel Off (HO)
5. Pre-Swing/ Toe Off (TO)

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Sagittal Plane

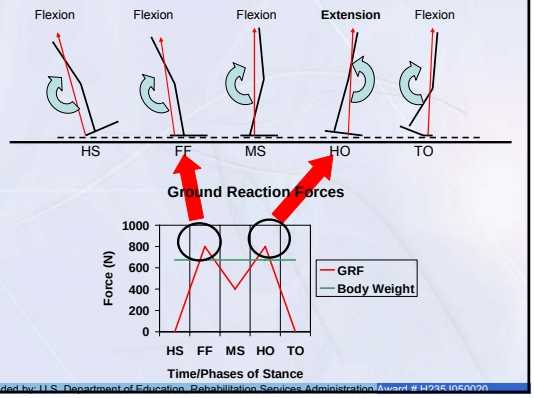
With regard to the anatomic ***knee*** during *normal* gait, where is the ground reaction force (GRF) vector during the 5 phases of stance?

In normal locomotion, there is an extension moment at the knee at Heel Off



Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Sagittal Plane Knee Moment:

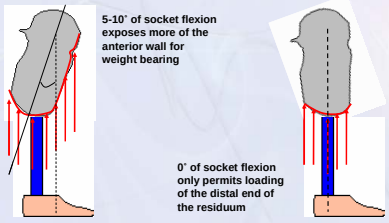


Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Flexion Moment

So, to encourage flexion at HO:

- Pre-flex the socket/Dorsiflex the foot
- Use shorter/less firm keel
- Move the foot posterior



Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

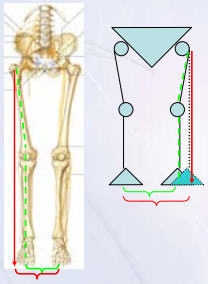
Flexion Moment

- In trans-tibial gait, a flexion moment is desired in all phases of stance
  - From HS to FF, flexion will dampen shock &
  - smooth out COM rise/fall
    - As in normal gait
- An extension moment at HO
  - Would likely be uncomfortable to tight, posterior structures
  - Can alter the duration of the prosthetic stance phase
  - Can cause gait deviations
- To align for an extension moment at HO,
  - Stance flexion may be interrupted
  - Shock attenuation may then be compromised

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Frontal Plane

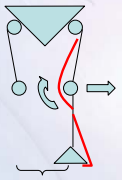
- In normal anatomy:
  - Femur is ADDucted causing
  - Valgus knee alignment
- Valgus Knee Anatomically
  - Decreases BOS
  - Requires less lateral shift
    - To position COM over BOS
    - Less energy expenditure
  - Is controlled with muscle…



Gray's Anatomy

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

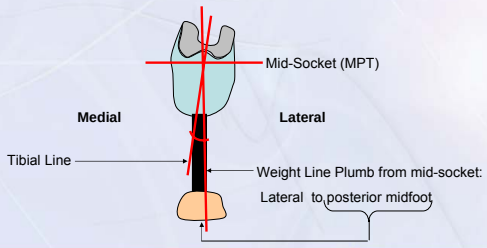
- Muscles that *normally* check Valgus include:
  - Knee:
    - Pes Anserinus
      - Semitendinosus
      - Gracilis
  - Ankle:
    - Peroneal Group (Eversion)



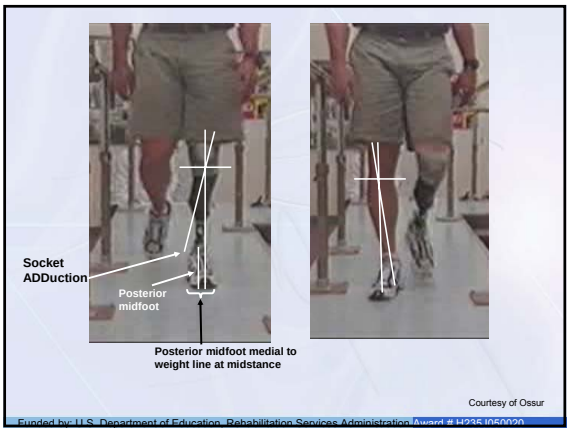
Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

- Prosthetically-
  - Slight varus is desired
  - Socket is ADDucted on pylon
  - Foot is inset
    - relative to weight line passing through Mid-Socket

Posterior View of a Right Prosthesis:



Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020



Courtesy of Ossur

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Varus Moment

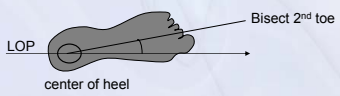
Slight varus moment at midstance is the goal

- Slight Varus moment
- Is comfortably tolerated
- Stresses the tough lateral co-lateral knee ligament (LCL)
  - As opposed to the thinner medial co-lateral ligament (MCL)
  - & because muscular valgus restraint is disadvantaged
  - Tibia is not rigidly anchored to floor
    - **Flexible interface material allows movement within the socket**
  - No foot/ lower leg musculature stabilizing Tibia on Foot
- Narrows BOS/ increased gait efficiency

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Transverse Plane

- Socket fit will dictate its own transverse location on the limb
- Toe out is the other consideration
- Normal Toe out is ≈ 7˚
- Toe out increases with increasing velocity



Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Toe Out

Match the sound side
- Cosmetically
- At typical speed for the individual

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Properly Aligned

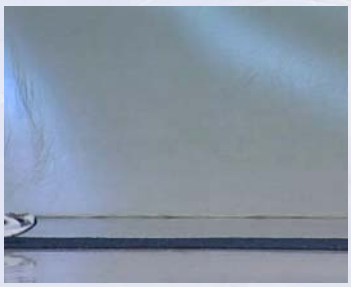
Observe:
- All Planes
- Frontal:
  - Toe out
  - Slight Varus

Courtesy of Ossur

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Properly Aligned

Observe:
- Sagittal:
- Slight Flexion Moment



Courtesy of Ossur

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Gait Deviations…

- Sagittal Plane:
  - Extension Moment
  - Flexion Moment
- Frontal Plane:
  - Varus Moment
  - Valgus Moment
- Transverse Plane:
  - Toe In
  - Toe Out

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Extension Moment

Extension moment during stance:

- Foot reaches stable foot flat too rapidly
  - Causes ground reaction force to advance anterior to knee
- Causes knee to extend as
  - Body mass progresses over the extended knee
- Uncomfortably stretches tight posterior structures:
  - Hamstrings
  - Joint capsule
  - Many amputees will have a contracture or posterior tightness

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Extension Moment

- May be early in Stance Phase
- May be late in Stance Phase
  - It depends on the cause…

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Extension Moment

Prosthetic-related causes:

- Heel too soft
- Socket too extended/ foot too plantar flexed
- Socket too far posterior/ foot too anterior

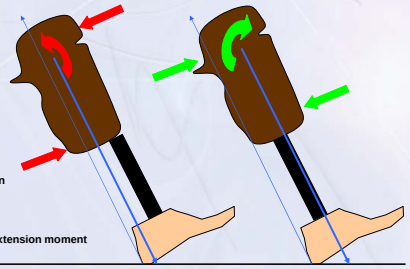
Patient-related causes:

- Excessive quadriceps activation
- Weak quadriceps
- Patient changed to a lower heeled shoe

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Extension Moment

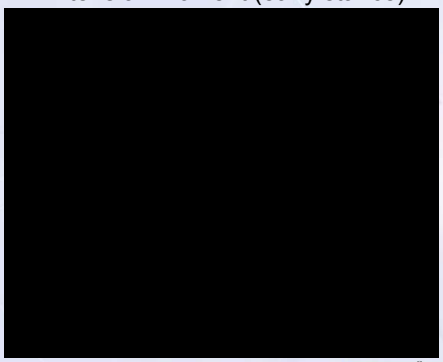
- **HS- Heel lever decreased with** anterior foot
- Soft heels **can effect ground reaction forces similarly**



•**Anterior Foot Position**
•**Soft Heels**
•**Plantar Flexed Foot**
…can yield an *early* extension moment

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Extension Moment (early stance)

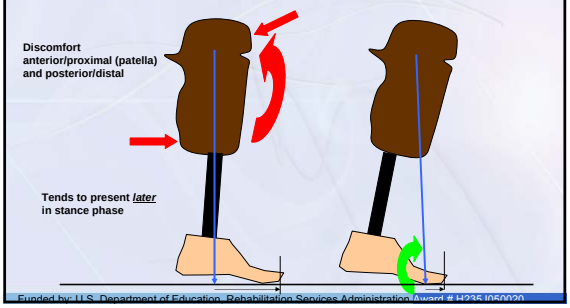


Courtesy of Ossur

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Extension Moment

HO→ TO- Toe lever is increased with an anteriorly placed foot

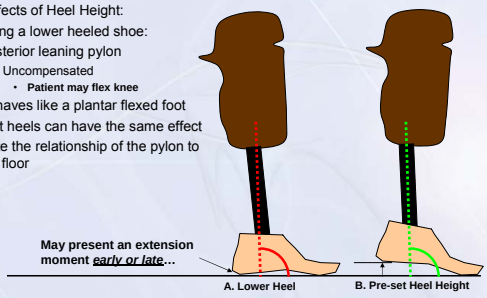


Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Extension Moment

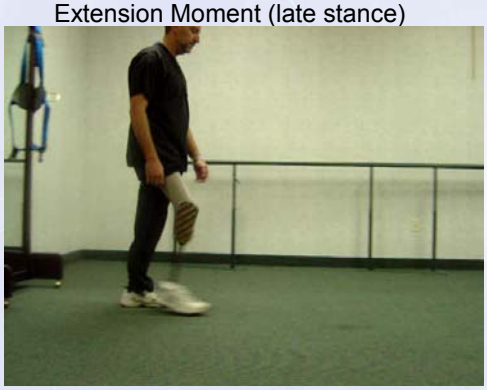
The effects of Heel Height:

- Using a lower heeled shoe:
- Posterior leaning pylon
  - Uncompensated
    - Patient may flex knee
- Behaves like a plantar flexed foot
- Soft heels can have the same effect
- Note the relationship of the pylon to the floor



Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Extension Moment (late stance)



Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Extension Moment: Unique, Foot Dependant Case: Foot Slap

- Single Axis (SA) foot
- The SA foot has anterior & posterior bumpers
- The posterior bumper acts as the dorsiflexor muscles
- To “eccentrically” plantar flex the foot at HS (or initial contact IC)

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Foot Slap

- If the posterior bumper is
  - too soft
  - worn out,
  - or is under insufficient compression,
- The foot will offer little resistance to plantar flexion at Heel Strike

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Foot Slap

- This causes the foot to reach foot flat too quickly generating an extension moment
- Sometimes making an audible “slap”

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Flexion Moment

- At HS- foot takes too long to reach foot flat
  - Knee buckles
- Ground reaction force falls posterior to the knee
- From HO through TO- there may be an insufficient toe lever
  - Premature loss of anterior support
  - Also known as “Falling off” or “Drop off”

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Flexion Moment

- May be early in Stance Phase
- May be late in Stance Phase
  - It depends on the cause…

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Flexion Moment

Prosthetic causes

1. Foot too far posterior/ socket too anterior
2. Foot too dorsiflexed/ socket too flexed
3. Heel too firm
4. Heel height too tall
5. Keel too short or soft

Patient-related causes

1. Weak knee extensors
2. Resolving flexion contracture causing excess socket flexion
3. Patient changed to higher heeled shoe

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

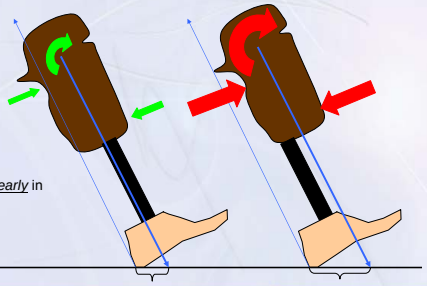
Flexion Moment

- Pressure anterior/distal
  - At the sensitive, cut end of the Tibia and
- Posterior/Proximal
  - Near the hamstring tendons

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Flexion Moment

- Posterior placed foot (anterior socket) increases heel lever
- Firm & high heeled shoes cause similar reactions



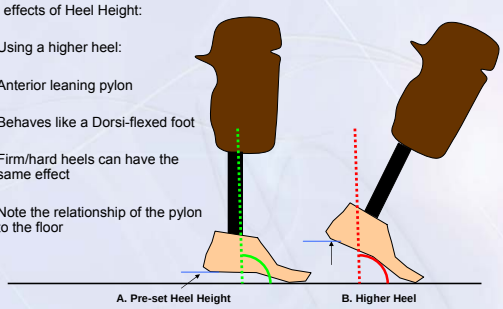
Tends to present *early* in stance phase

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Flexion Moment

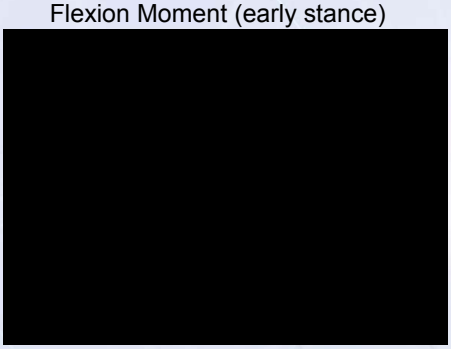
The effects of Heel Height:

- Using a higher heel:
- Anterior leaning pylon
- Behaves like a Dorsi-flexed foot
- Firm/hard heels can have the same effect
- Note the relationship of the pylon to the floor



Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Flexion Moment (early stance)

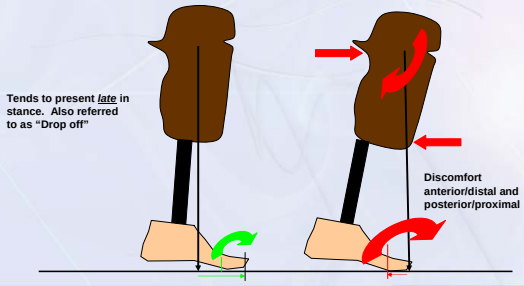


Courtesy of Ossur

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Flexion Moment

- From HO thru TO, a posteriorly placed foot
  - Decreases toe lever- minimizing anterior support
  - Short or soft Keel levers behave similarly



Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Flexion Moment (late stance)

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Valgus Moment

- Observed from the coronal plane at midstance
- GRF passes lateral to Knee's center of rotation (COR) in the frontal plane
- Distal Tibia rotates laterally relative to Femur

Shurr DG, Michael JW

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Valgus Moment

- There are few muscles to resist Valgus forces
  - Remember, the peroneals are not intact
  - This leaves the pes anserine group
- Weaker ligaments to resist this motion:
- Medial (Tibial) Collateral Ligament (MCL)
  - MCL
    - Is thin & broad
    - Posterior Part is enmeshed into the knee's joint capsule
    - Attached to the medial meniscus
    - Originates at the medial epicondyle of the knee
    - Inserts medially/proximally on the Tibia
    - The MCL's anterior portion is tight in all positions
    - The posterior portion is loose in all positions but extension

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Valgus Moment

- Pressure is applied from interface to limb
- Proximal/lateral
  - Near the fibula head
- Distal Medial
  - Cut end of Tibia
- This alignment
  - is not generally comfortable
  - abnormally stresses the knee

Shurr DG, Michael JW

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Valgus Moment

Prosthetic causes

1. Foot too outset/ socket too inset
2. Foot too Abducted (socket too ADDucted)
3. Prosthesis is too long
4. Socket is uncomfortable

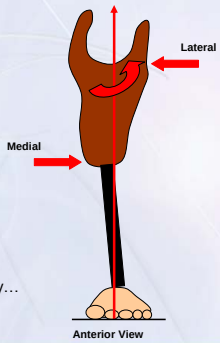
Patient-related causes

1. Tends to walk with wide base of support
2. Hip ABduction contracture
3. Structural Deformity

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Valgus Moment

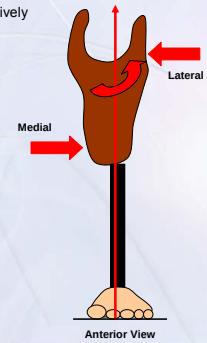
- Pressure is applied from interface to limb
- Proximal/lateral
  - Near the fibula head
- Distal Medial
  - Cut end of Tibia
- This alignment
  - is not generally comfortable
  - abnormally stresses the knee
- In this schematic, the socket is in excess ADDuction & the pylon is leaning medially…



Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Valgus Moment

- In this schematic, the foot is outset excessively yet the pylon is vertical.
- Valgus forces can still be generated in the presence of a vertical pylon…



Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Valgus Moment

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Varus Moment

- Observed from the coronal plane at midstance
- GRF passes Medial to Knee's COR in the frontal plane
- Distal Tibia rotates Medially relative to Femur
- Very few muscles to resist this rotation
- Strong, extracapsular ligament to resist this motion
- Lateral (Fibular) Colateral Ligament (LCL)
  - **LCL**
    - Is a thick, cord-like band
    - Originates at the lateral epicondyle of the knee
    - Inserts upon the fibula head
    - Separate & Free of the joint capsule
    - Taught in knee extension; loose all other positions

Shurr DG, Michael JW

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Varus Moment

- Pressure is applied from interface to limb
- Proximal/Medial
  - Depending on trimlines either:
  - Near the Vastus Medialis/Medial condyle (with Supracondylar trimlines)
  - Near the Medial Femoral Condyle or In the medial Tibial Flare (with standard Patella Tendon Bearing and lower trimlines)
- Distal Lateral
  - Cut end of Fibula- highly irritable

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Varus Moment

- **This alignment**
  - is normal when in the appropriate quantity
  - Stresses the more tolerant of the two collateral ligaments
    - LCL as opposed to the MCL
  - Provides a narrow based gait
  - Mimics normal gait
  - If excess
    - Can irritate structures in the medial condylar area
    - Can irritate the distal cut end of the fibula if not sufficiently relieved

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Varus Moment

Prosthetic causes

- Foot too inset/ socket too outset
- Foot too ADDucted (socket too Abducted)
- Prosthesis is too short
- Socket is uncomfortable

Patient-related causes

- Tendency of a narrow-based gait
- ADDuctor tightness
- Other habit-type deviations such as circumduction may contribute

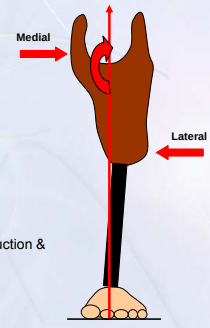
Shurr DG, Michael JW

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Varus Moment

Pressure is applied from interface to limb

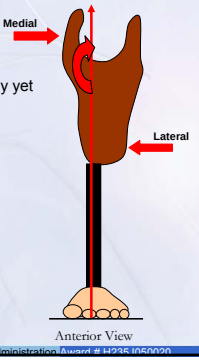
- Proximal/Medial
  - Near the Medial Femoral Condyle
  - Vastus Medialis Muscle
- Distal Lateral
  - Cut end of Fibula
- This alignment
  - is generally comfortable when appropriate
  - BUT can abnormally stress the knee
- In this schematic, the socket is in excess ABduction & the pylon is leaning laterally…



Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Varus Moment

- In this schematic, the foot is inset excessively yet the pylon is vertical.
- Varus forces can still be generated in the presence of a vertical pylon…



Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Varus Moment

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Excess Toe In

Foot asymmetry is most noticeable in the *coronal plane* (from foot flat to toe off)

Figure A depicts prosthetic stance and Figure B depicts sound side stance. Note the excess toe in of Figure A relative to Figure B.

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Excess Toe In

The associated gait deviation (if any) is most noticeable in the ***sagittal plane*** (typically a late stance extension moment)

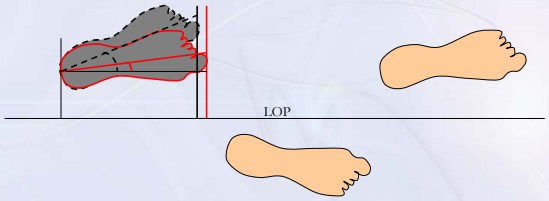
Note the degree of knee extension as the person advances into toe off

though the problem is in the *transverse plane…*

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Excess Toe In

- Increasing the quantity of toe in effectively lengthens the foot.
- A longer toe lever can create a knee extension moment late in stance…



- If the deviation is not this severe, the excess Toe In will only be observed as an asymmetry relative to the other foot.

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Excess Toe In

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Excess Toe Out

Foot asymmetry is most noticeable in the *coronal plane* (from foot flat to toe off)


A.


B.

Figure A depicts prosthetic stance and **Figure B** depicts sound side stance. Note the excess toe out. It is quite a bit more noticeable than excess toe in. The associated deviation(s) are unique as well…

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Excess Toe Out

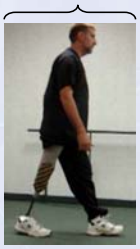
- Recall that the gait deviation generally associated with excess Toe in is noticeable in the *sagittal plane*. It is commonly seen in late stance as an extension moment. If it is not severe enough, then it will only be observed as an asymmetry in the frontal plane.
- With Excess Toe Out, the gait deviation(s) are two fold:
  1. The toe lever is shortened so a **Flexion moment** may be appreciated (***sagittal plane***)
  2. Medial support is lost as well (comparable to an outset foot) so a **Valgus moment** results (***coronal plane***)
- Remember, the underlying problem is in the *transverse plane*…

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Excess Toe Out

Compare Gait Deviations between **Toe In** vs **Toe Out**…

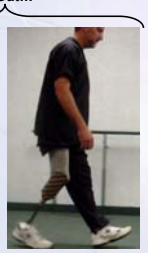
Toe In…



Note the degree of knee extension here with excess *Toe In*

Toe Out…

Note the Valgus Moment due to loss of medial support with Excess *Toe Out*

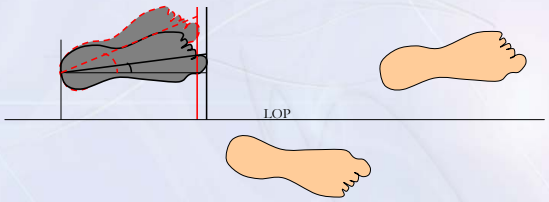


Note the degree of knee flexion here with Excess *Toe Out*

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Excess Toe Out

- Decreasing the quantity of Toe In effectively shortens the foot.
- A shorter toe lever can create a late flexion moment…

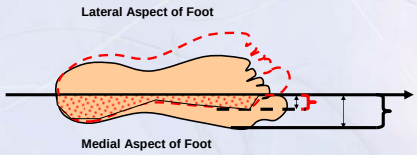


- Even though the root cause is in the transverse plane, this will be noticed in the sagittal plane. However…

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Excess Toe Out

In addition to the loss of toe length, there is a loss of Medial Support…



- Even though the root cause is in the ***transverse plane***, this will be noticed in the ***sagittal plane*** as a Valgus Knee Moment…

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Excess Toe Out

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Swing phase deviations

- While the majority of gait deviations in the trans-tibial prosthesis user are prosthetic stance deviations.
- Deviations do appear in prosthetic swing phase.
- Example…

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Swing phase deviations

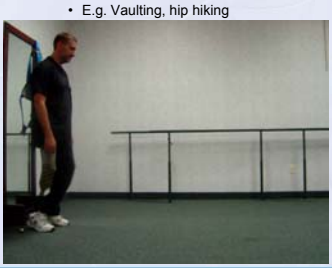
- Poor suspension (scuffing toe, pistoning, rotating)
- If the prosthesis loses suspension and slips toward the floor when it is swinging forward, deviations may result.
- When the prosthesis is slipping, due to poor suspension, it is said to be "pistoning"

Dramatization of pistoning

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Swing phase deviations

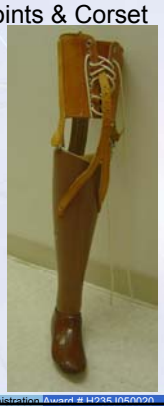
- Pistoning can
  - Wear components
  - Cause tissue trauma
  - Cause deviations as the prosthesis is effectively longer
    - E.g. Vaulting, hip hiking



Vaulting is rising up on the sound side toe with plantar flexion

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Special Case: **Prosthosis** Joints & Corset



- Combining a prosthesis and orthosis yields a device called a **prosthosis**.
- Probably, the most common prosthosis is the Joints & Corset Design, trans-tibial prosthesis.

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Special Case: Prosthosis Joints & Corset (thigh cuff)

- It combines the foot replacement and socket interface typical of a trans-tibial prosthesis
- With orthotic knee joints and a thigh corset for load distribution…

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Special Case: Prosthosis Joints & Corset

- Mal-aligned side joints can cause problems with gait and other functions such as sitting.
  - In sitting, mal-aligned joints may cause the residual limb to be pulled out of the interface, rotated or cause other such complications
- Joints may be mal-positioned/ mal-aligned relative to
  - Anatomic knee center height or orientation in any of the cardinal planes or relative to one another
  - Deviations such as whips, not otherwise experienced with trans-tibial prostheses, may result
  - Tissue trauma & discomfort may result

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Special Case: Prosthosis Joints & Corset

- Video of individual with bilateral trans-tibial amputations and bilateral joint & corset check socket prostheses.
- In this case, no significant gait deviations are noted.

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Other Issues

- In trans-tibial gait, prosthetic users are often strong enough to influence the device as much as they may be influenced by the device.
- That is, a deviation may appear to be one problem but the user may be compensating.
- This may change with fatigue…

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Other Issues

- Many times, deviations are very subtle and may be visually undetectable during visual gait observation.
- The Clinician may have to rely on evaluation/inspection of
  - Patient/client reports or complaints
  - Skin redness
  - Shoe wear
  - Component wear
- **Deviations in this presentation are exaggerated for illustrative purposes. They are not necessarily indicative of the magnitude, extent or severity of TT gait deviations in all cases.**

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

References

1. Seelen HA, Anemaat S, Janssen HM, Deckers JH. Effects of prosthesis alignment on pressure distribution at the stump/socket interface in transtibial amputees during unsupported stance and gait. Clin Rehabil. 2003 Nov;17(7):787-96.
2. Chow DH, Holmes AD, Lee CK, Sin SW. The effect of prosthesis alignment on the symmetry of gait in subjects with unilateral transtibial amputation. Prosthet Orthot Int. 2006 Aug;30(2):114-28.
3. Van Velzen JM, Houdijk H, Polomski W, Van Bennekom CA. Usability of gait analysis in the alignment of trans-tibial prostheses: a clinical study. Prosthet Orthot Int. 2005 Dec;29(3):255-67.
4. Lin MC, Wu YC, Edwards M. Vertical alignment axis for transtibial prostheses: a simplified alignment method. J Formos Med Assoc. 2000 Jan;99(1):39-44.
5. Blumentritt S, Schmalz T, Jarasch R, Schneider M. Effects of sagittal plane prosthetic alignment on standing trans-tibial amputee knee loads. Prosthet Orthot Int. 1999 Dec;23(3):231-8.
6. Prosthetics-Orthotics Center, Northwestern University Medical School. Course Manual for Prosthetics 621: Transtibial Prosthetics for Prosthetists. Chicago, IL. 09/2003.
7. Shurr DG, Michael JW. Prosthetics and Orthotics. 2nd ed. Pearson Education, Inc. ©2002. ISBN 0-8385-8133-1

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

References

8. Netter FH. Atlas of Human Anatomy. 2nd ed. Icon Learning Systems. ©1997. ISBN 0-914168-80-0.
9. Nordin M, Frankel VH. Basic Biomechanics of the Musculoskeletal System. 3rd ed. Lippincott Williams and Wilkins. ©2001. ISBN 0-683-30247-7.
10. Drake RL, Vogl W, Mitchell AWM. Gray's Anatomy for Students. Elsevier Inc. ©2005. ISBN 0-443-06612-4.
11. American Academy of Orthopaedic Surgeons. Atlas of Amputations and Limb Deficiencies: Surgical, Prosthetic, and Rehabilitation Principles. 3rd ed. Smith DG, Bowker J, Michael J. Mosby Co. ©2002.
12. Otto Bock Health Care. www.ottobockus.com
13. Ossur. www.ossur.com

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

The University of South Florida would like to thank the following individuals, manufacturers and agencies for making this presentation possible:

- Westcoast Brace & Limb of Tampa, FL
  Jason T. Kahle, CPO
  Director of Lower Extremity Prosthetics
  Brian Whitacre
  Chief Orthotic Technician
- Ossur Prosthetics
- Otto Bock Healthcare

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

For further about the content of the module, contact

University of South Florida
dpt@health.usf.edu
(813)974-8870
Fax: (813)974-8915

Westcoast Brace & Limb
www.wcbl.com
(813)985-5000
Fax: (813)985-4499

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020

Funded by the Department of Education, Rehabilitation Services Administration
Award# H235J050020
"Demonstration Project on Prosthetics and Orthotics"

University of South Florida
College of Medicine: School of Physical Therapy & Rehabilitation Sciences
College of Engineering: Mechanical Engineering Department

M. Jason Highsmith, PT, DPT, CP, FAAOP
William S. Quillen, PT, PhD, SCS, FACSM
Rajiv Dubey, PhD

Funded by: U.S. Department of Education, Rehabilitation Services Administration Award # H235J050020