Gait training and Prosthetic KNEES

Part 1

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Outline

- Part 1
  - Human Knee Function
  - Identifying Mobility Priorities
    - Control Vs stability
  - Gait
    - Gait cycle
    - Normal gait
    - Prosthetic gait
    - Points for training
- Part 2
  - Prosthetic Knee Systems – Ossur Knees
    - Demonstration
    - Mobility Functions & Benefits
    - Candidate Selection

Complex Choices

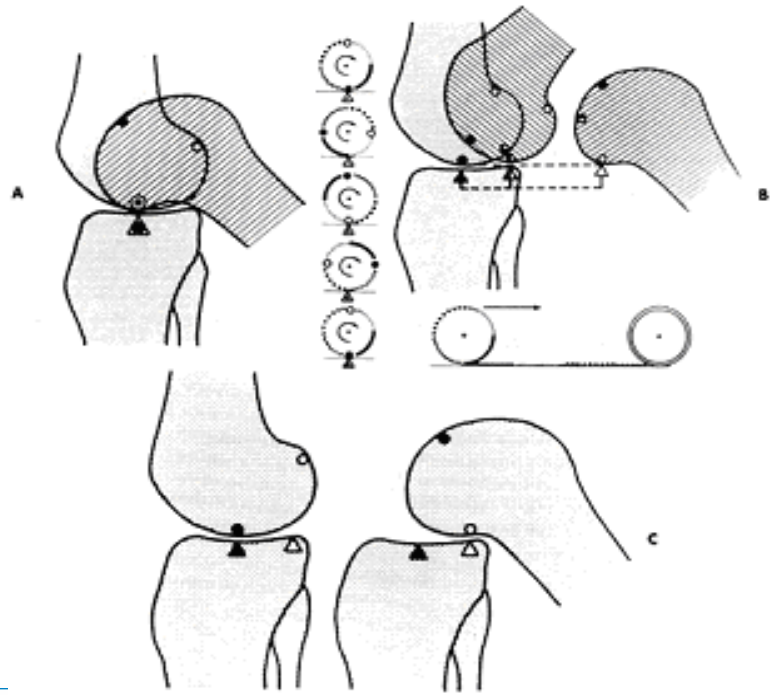
Selecting Appropriate Technology

- Anatomical knee provides:
  - multitude of functions

The knee joint

Normal Human Knee Function

- The human knee joint is a rolling, sliding, gliding polycentric joint which is yet to be fully functionally duplicated.



Functions of the knee joint & knee musculature

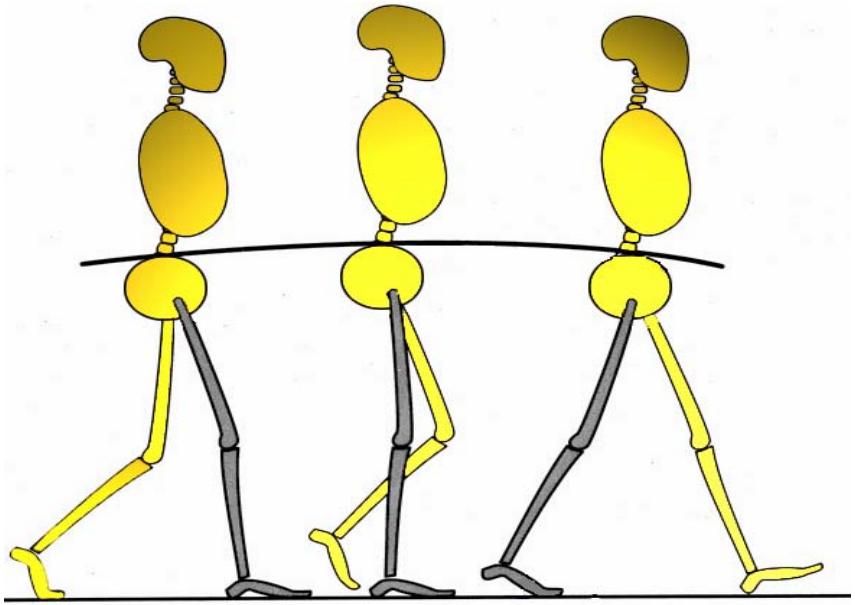
- Main functions
  - support during stance
  - shorten the leg during swing to allow clearance

- Others
  - impact absorption during weight acceptance (*quadriceps*)
  - prevent centre of mass rising during stance
  - decelerate shank (damping extension stop) during terminal swing (*hamstrings*)
  - adaptation to variable cadence - prevention of heel-rise (*rectus femoris*)
  - allow sitting.

Normal Biomechanics

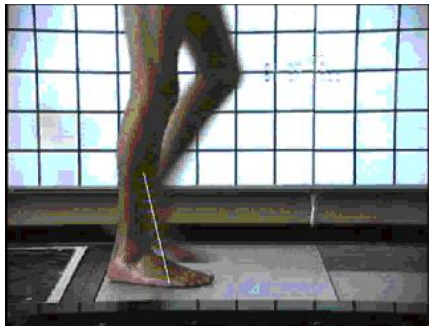
How we move:

- Phases of Gait Cycle
- Pelvic excursion
- Postural Sway

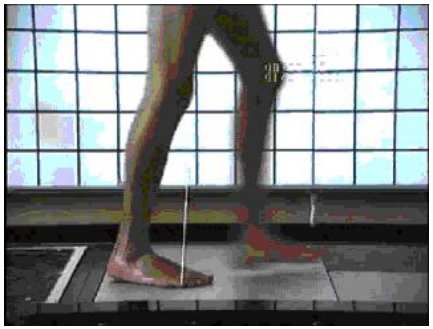


Muscle function & Ground Reaction Vector

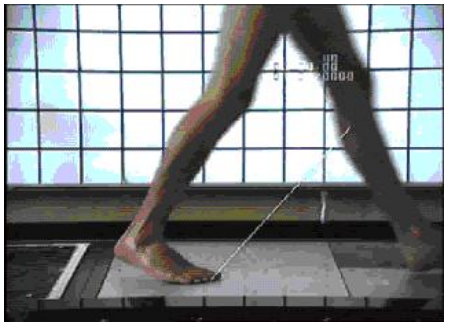
Knee unstable



Knee unstable



Knee stable



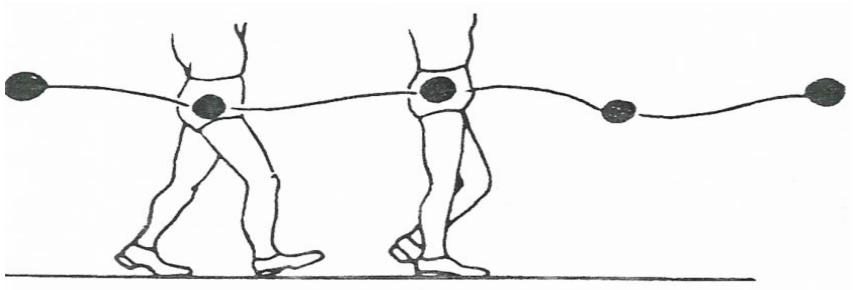
Knee stable

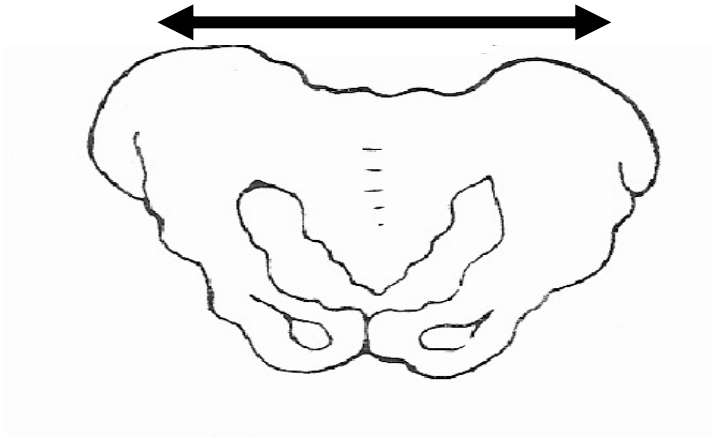
- when GRV is posterior to knee axis, knee must be stabilized by hip extensors (*gluteus maximus*)
- at toe-off GRV is anterior and knee must be unlocked by hip flexors (*iliopsoas*)

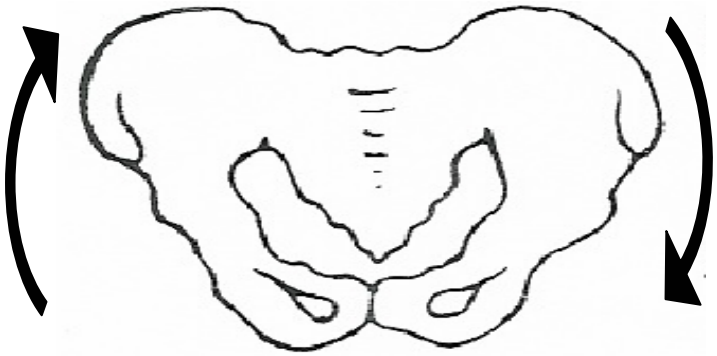
Pelvic movement During Gait

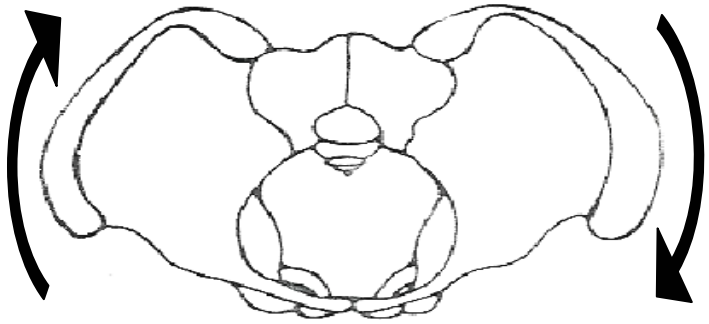
- Anterior/Posterior rotation
  - Rotation of the pelvis about the vertical axis
- Vertical tilt
  - Rotation of the pelvis around the horizontal axis
- Anterior/Posterior tilt
  - Rotation of the pelvis about the transverse axis
- Anterior/Posterior shift
  - Movement of the pelvis forwards and backwards
- Lateral shift
  - Movement of the pelvis from side to side

Pelvic Excursion



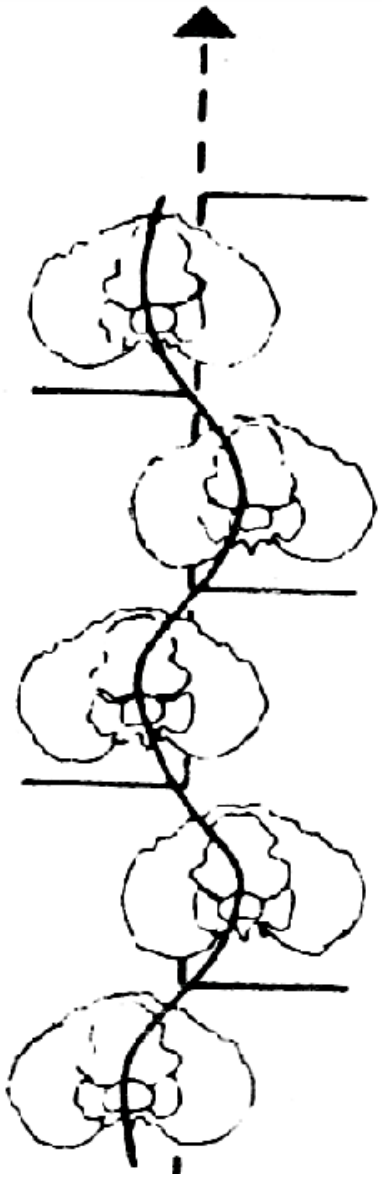






Postural Sway

- Smooth movement
- Balanced segments
- Energy efficient
- Effortless



Types of Prosthetic Knees

- There are many different knee joints available on the market

- All knee joints must meet certain mechanical criteria
  - Capable of flexing (preferably to 120°)
    - Sitting
    - During swing
  - Requires both friction and extension bias mechanisms
  - Stable under load, achieved by:-
    - Structure of the joint
    - Alignment
    - Proximal muscle activity
    - A shorter stride

Types of Prosthetic Knees

- For prescription and training it is important for Physiotherapists to be aware of the characteristics and differences of the knee joints and their functionality:
  - Whether they “lock” in stance phase
  - How they “release” for swing phase
  - Will they allow flexion under load – stairs, ramps, sitting?
  - Ability to engage / disengage hydraulics

- **Not all knees will have the same advantages / disadvantages!**

Complex Choices

Selecting Appropriate Technology

- Anatomical knee provides:
  - multitude of functions
- Mechanical prosthetic knees typically provide:
  - ONLY one or two functions
- <u>The Task:</u> Must prioritize users physical abilities, needs and rehabilitation goals carefully

The Simple Solution

Selecting Appropriate Technology

- Consider **STABILITY (Stance Control)**
  - Providing a stable knee to balance the user's level of voluntary control
  - ***Functions to match mobility requirements***

- Consider **EFFICIENCY (Swing Control)**
  - Provide the proper swing control to minimize energy consumption
  - Maximize walking performance

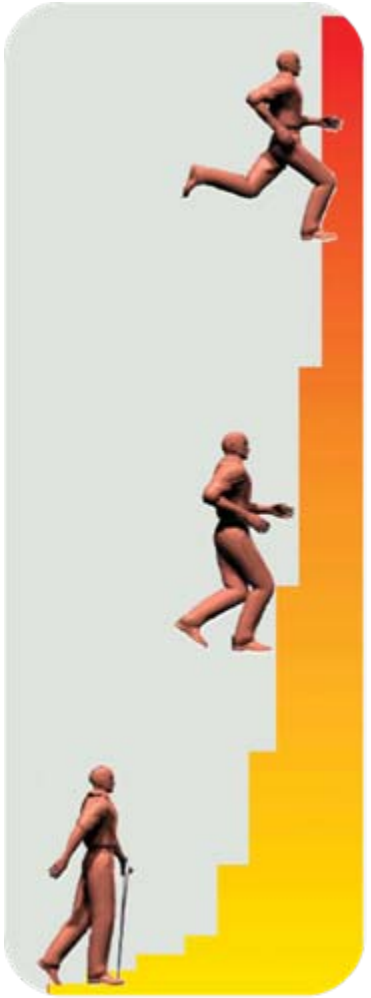
- Consider lifestyle needs – additional requirements

- Consider physical parameters (weight, clearance, etc.) and rehabilitation potential of the user

Voluntary Control

Addressing Mobility Priorities and Goals

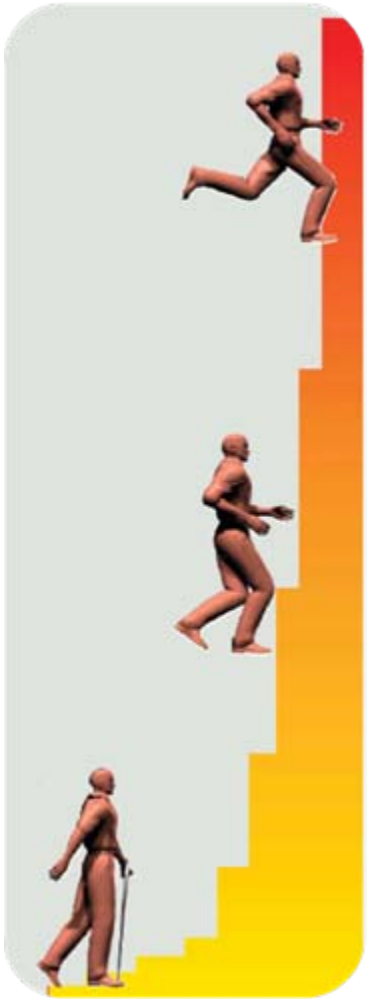
- What is the amputee´s mobility need and potential (based on environment and activities of daily living)?
  - Sitting
  - Standing
  - Transfer
  - Kneeling/ Squatting
  - Walking (level ground and/or uneven ground?)
  - Ramps (shallow and/or steep?)
  - Curbs
  - Stairs
  - Walk at constant or varying pace?
  - Walking, jogging, and running - athletics
  - Other – special need for certain activity



Voluntary Control

Addressing Mobility Priorities and Goals

- Subjective and Objective Assessment Tools:
  - Physical Assessment and Interview
  - Previous prosthetic use and experience
  - Amputee Mobility Predictor – Dr. Robert Gailey
    - AMP PRO
    - AMP NOPRO

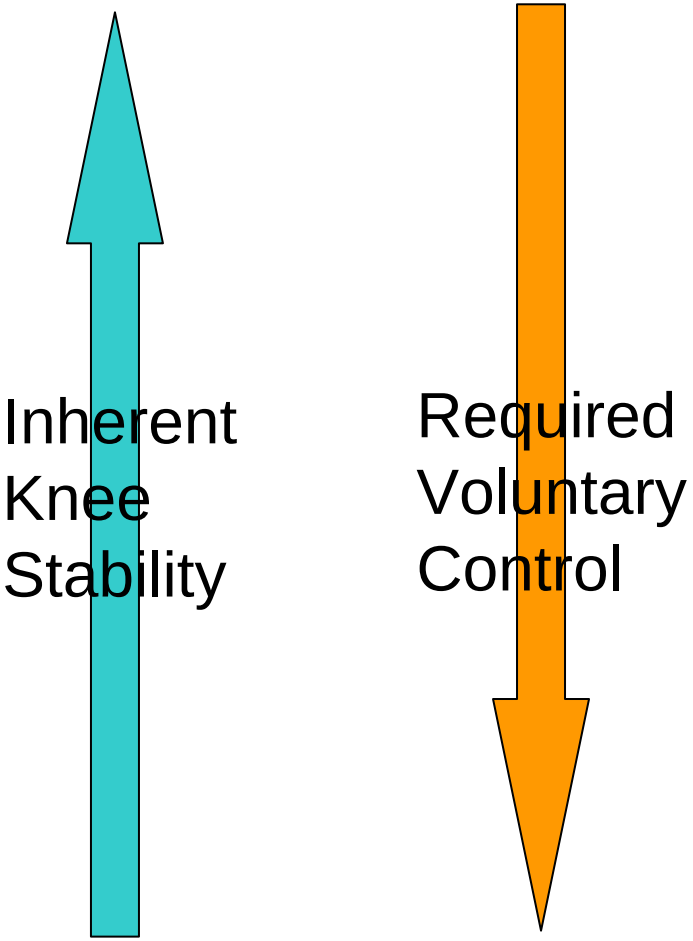


Voluntary Control vs. Knee Stability

Most Stable

- Manual Locking
- Microprocessor Control Stance
- Single Axis (Weight Activated Stance Control)
- **Polycentric with Geometric Lock - Össur Total Knee**
- Polycentric
- **Single Axis (Hydraulic Yielding Stance Control)**
  Össur Mauch Knee
- Single Axis – with no specific stance control

Least Stable



Key Examples:

- Single Axis (Weight Activated Stance Control)
  - Eg OB 3R49/90/92
- **Polycentric with Geometric Lock - Össur Total Knee 2000**
  - **Eg 1100/1900/2000/2100**
- Polycentric
  - OB 3R36/60/55/72/106
- **Single Axis (Hydraulic Yielding Stance Control)**
  Össur Mauch Knee 136/166
  - OB3R80
- Single Axis – with no specific stance control
  - OB 3R95

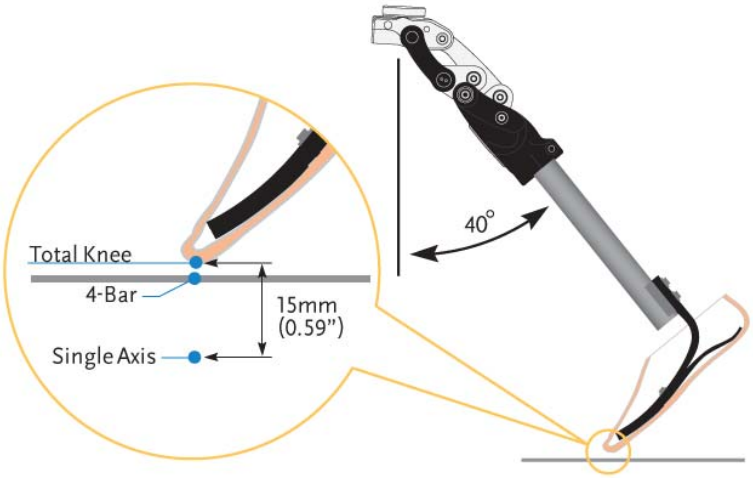
Key Concepts …

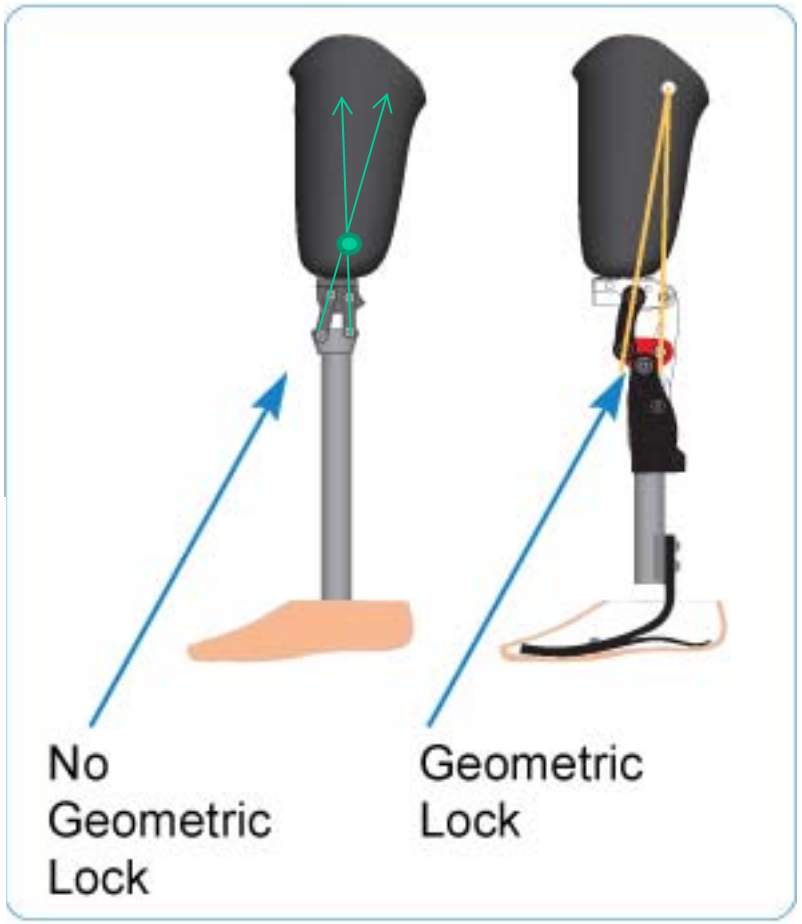
- Single Axis Concepts
  - **Yielding hydraulics**
  - **Increased resistance to Knee flexion**

Key Concepts …

Polycentric concepts

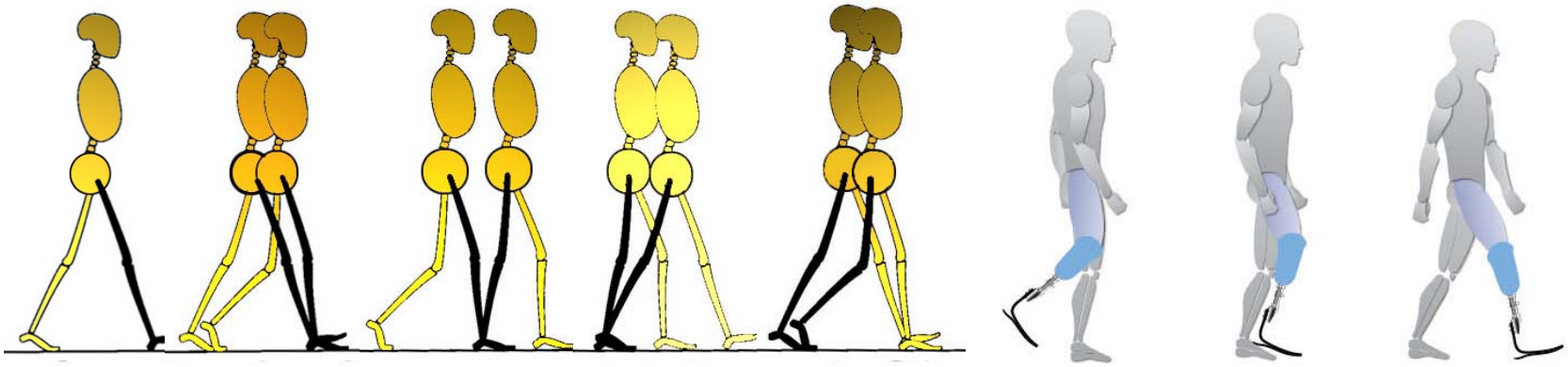
- **Instantaneous Centre of Rotation**
- **Linkages able to fold in swing**
- **Stance Flexion units**





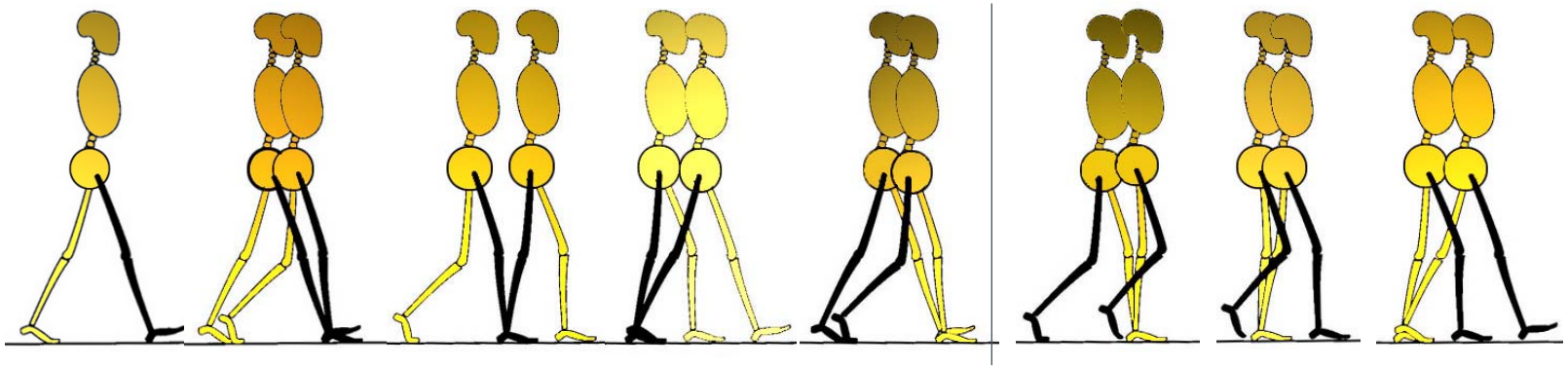
Reviewing the Gait Cycle …

Normal Versus Prosthetic Gait



Normal Gait Cycle

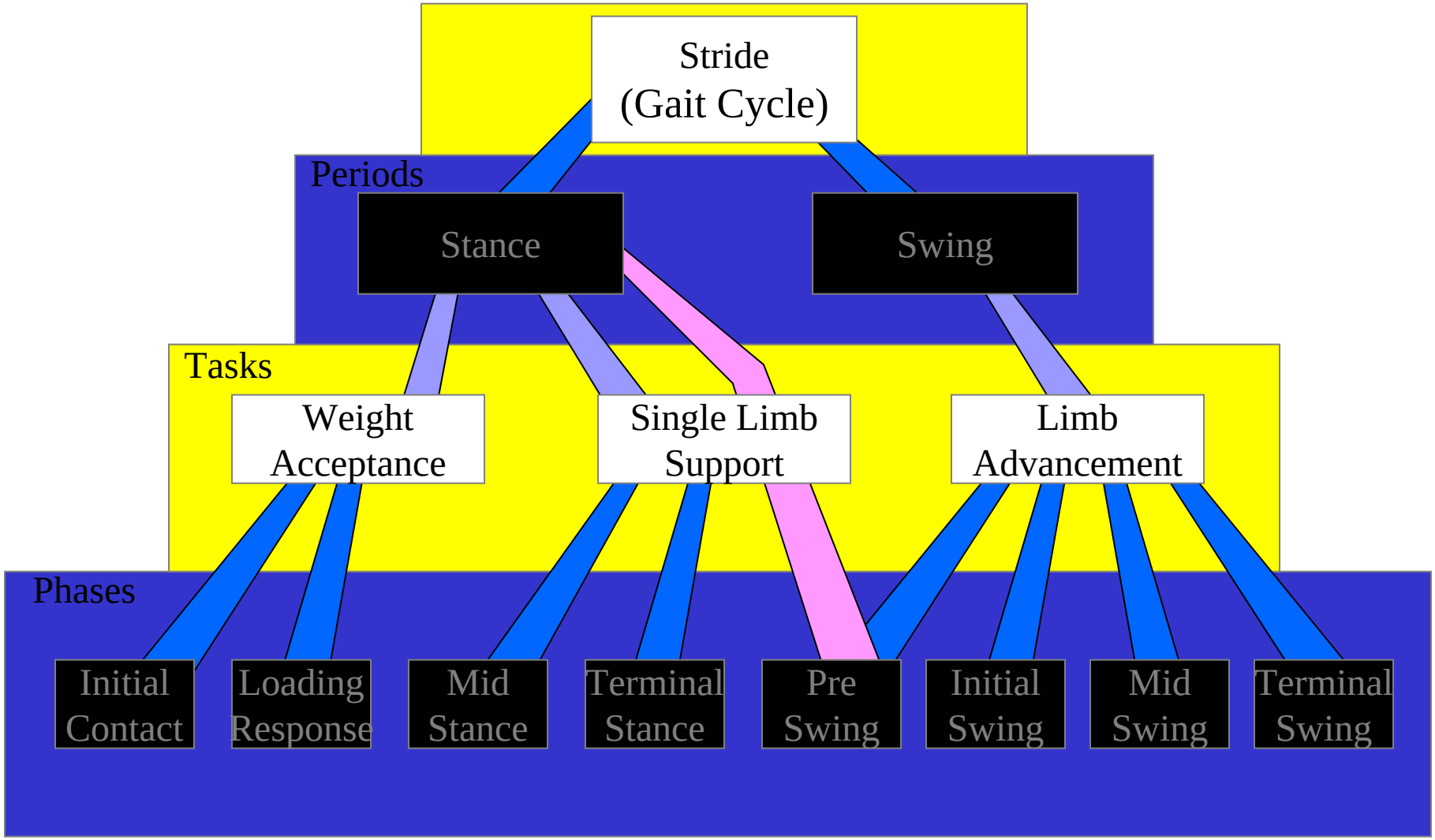
Stance Phase
Time the foot is in contact with the floor
Swing Phase
Time the foot is in the air



IC *LR* *Early MS* *Late MS* *TS* *PS* *MS* *TS*

Stance Phase **Swing Phase**

Divisions of the Gait Cycle

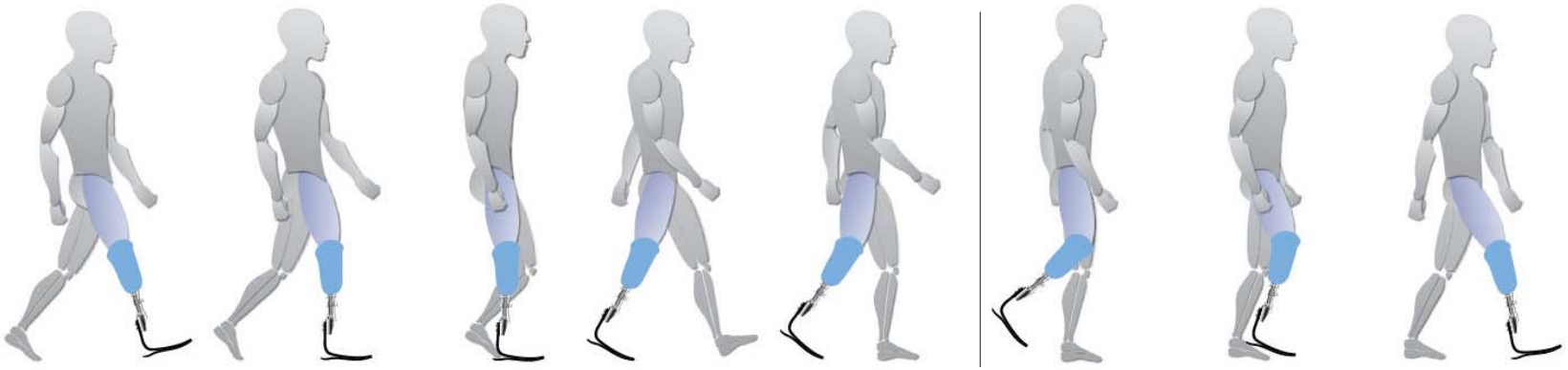


Normal Gait Cycle

Perry 1992	Inman 1981	
Initial Contact	Heel strike	(0 - 2% of the GC)
Loading Response	Foot Flat	(0 -10% of the GC)
Mid Stance	Mid Stance	(10 - 30% of the GC)
Terminal Stance	Heel Off	(30 – 50 % of the GC)
Pre-Swing	Heel Off - Toe Off	(50 – 60 % of the GC)
Initial Swing	Toe Off - Early Accel	(60 – 73 % of the GC)
Mid Swing	Mid Swing	(73 – 87 % of the GC)
Terminal Swing	Deceleration	(87 -100 % of the GC)

Prosthetic Gait Cycle

Stance Phase
Time the foot is in contact with the floor
Swing Phase
Time the foot is in the air

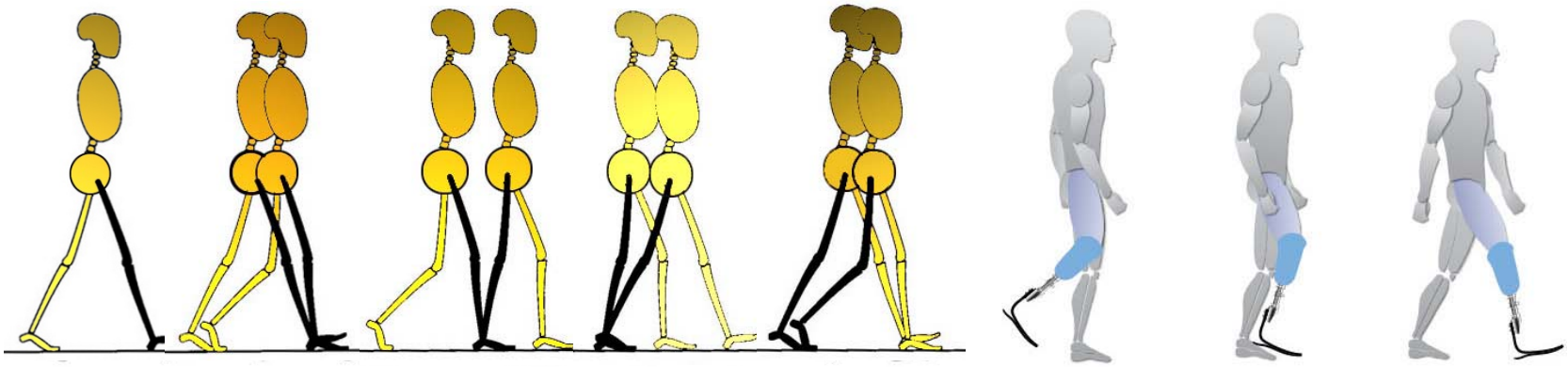


IC *LR* *Early MS* *Late MS* *TS* *PS* *MS* *TS*

Stance Phase **Swing Phase**

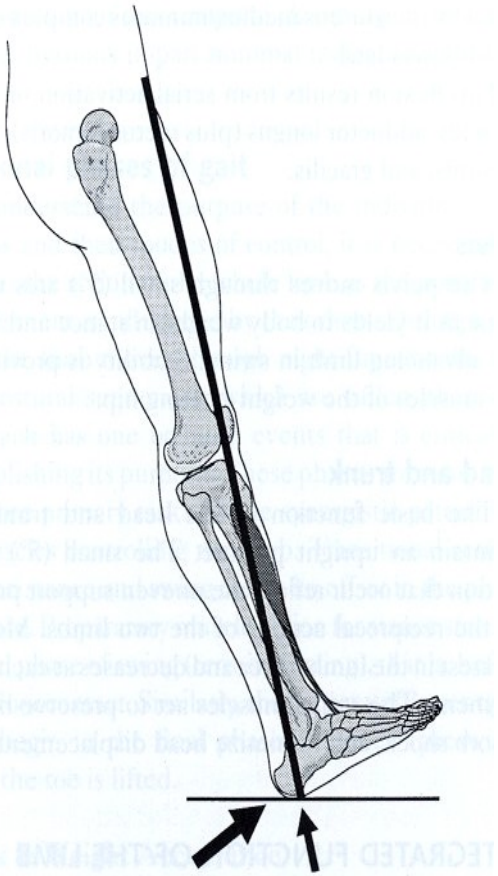
Individual phases of the gait cycle

Normal Versus Prosthetic



Stance Phase - Initial Contact

– Weight Acceptance

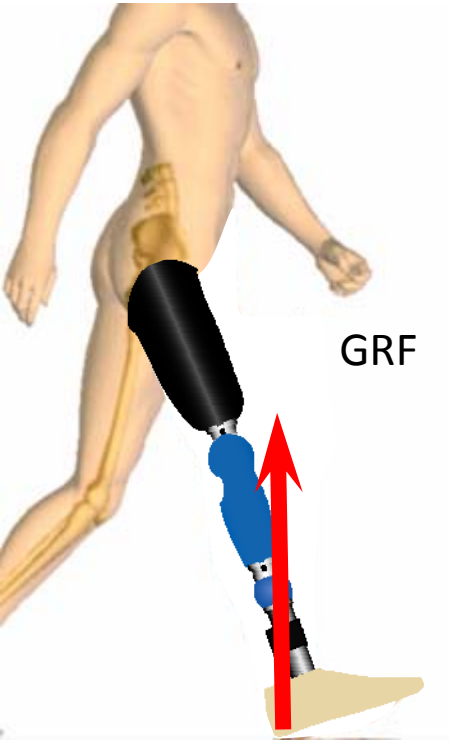


Initial Contact

- Objective:
  - Begin stance phase
  - First period of double support
- Active Muscles:
  - Knee flexors
  - Ankle dorsiflexors

Inman Term: Heel Strike

Prosthetic Knee Stance Phase: *Initial Contact*

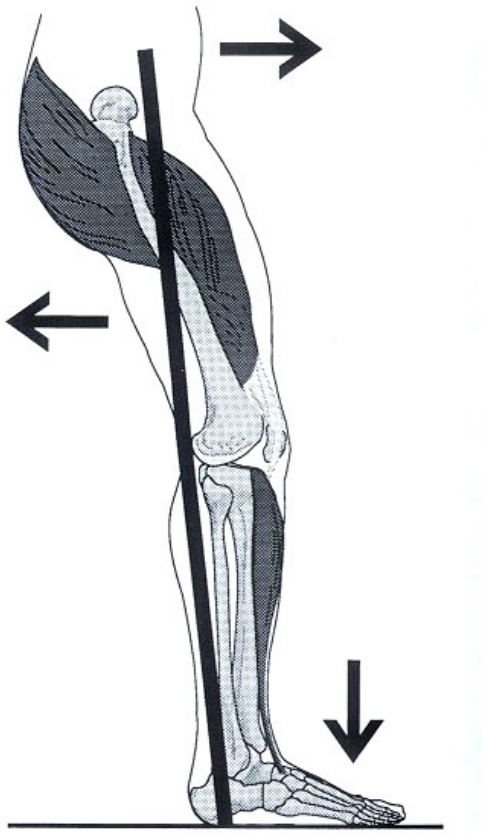


Initial Contact

- GRF: Ground Reaction Force
  - Anterior to Hip & Knee
  - Posterior to Ankle
- Joint Position:
  - Hip-Flexed
  - Knee-Extended
- Active Muscles:
  - Hip Extensors
- **All Knees**
  - **Extended in preparation for loading response**
  - ***Heel compression of foot***

Inman Term*: Heel Strike*

Stance Phase – Loading Response
– Weight Acceptance

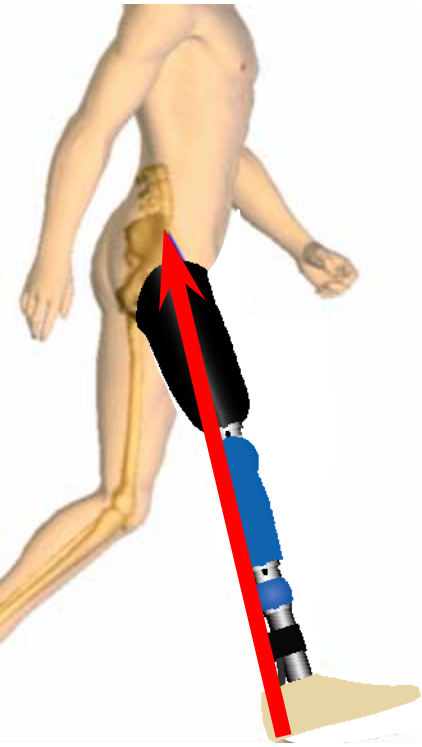


Loading Response

- Objective:
  - Optimum weight acceptance
  - Shock absorption through knee flexion
  - Weight bearing stability
  - [reservation of forward progression
  - Continues first period of double support
- Active Muscles:
  - Hip extensors
  - Knee extensors

Inman Term: Foot Flat

Prosthetic Knee Stance Phase: *Loading Response*



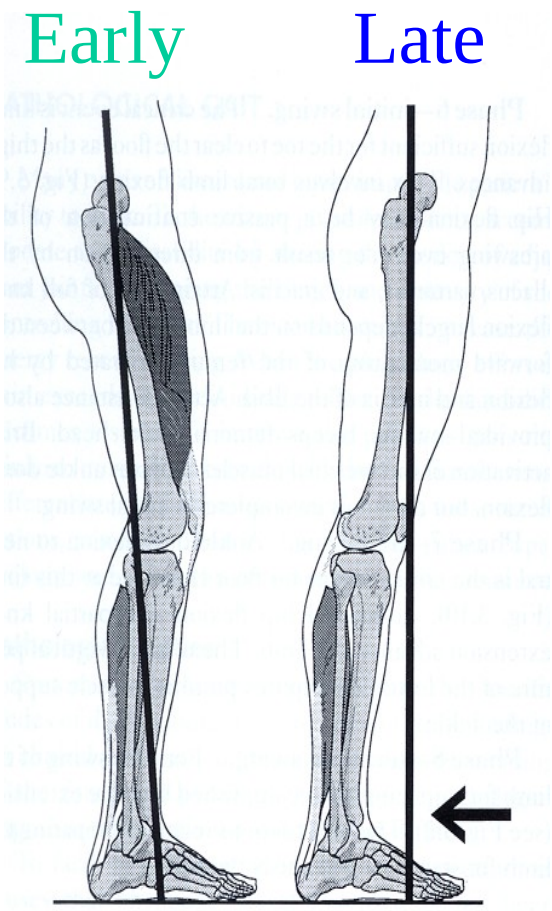
Loading Response

- GRF:
  - Anterior to Hip
  - Posterior to Knee & Ankle
- Joint Position:
  - Hip-Flexed
  - Knee-Flexed
  - Foot Flat – “Plantar Flexion” or heel compressed
- Active Muscles:
  - Hip extensors
- **Knee:**
  - **Stance flexion in some polycentric knees allows for the shock absorption**
  - **Some single Axis knees need to balance the foot compression to reduce the “jarring” effect.**

Inman Term: *Foot Flat*

Stance Phase – Mid Stance

- Single Limb Support

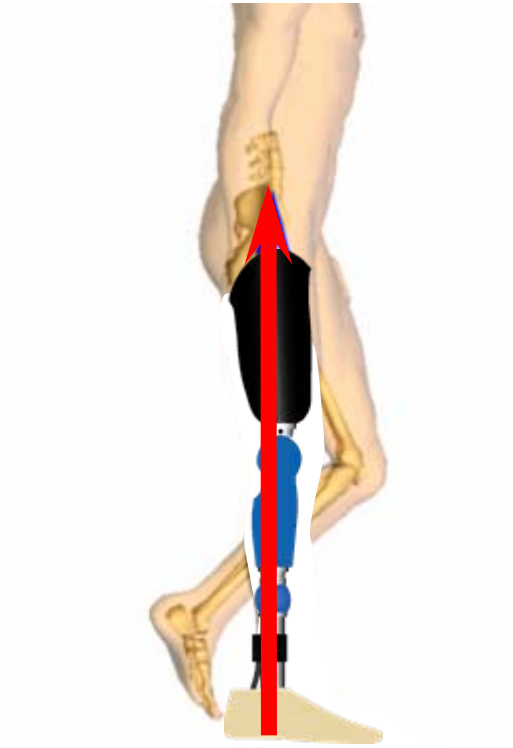


Mid-Stance

- Objective:
  - Begin stance limb support (full weight bearing requiring maximum stability)
  - Forward trunk and stance limb progression
  - Raise body- increase clearance for swing of contralateral limb
- Active Muscles:
  - Early: Knee Extensors, plantar flexors.
  - Late: Plantar flexors

Inman Term: Mid-Stance

Prosthetic Knee Stance Phase: *Mid-Stance*



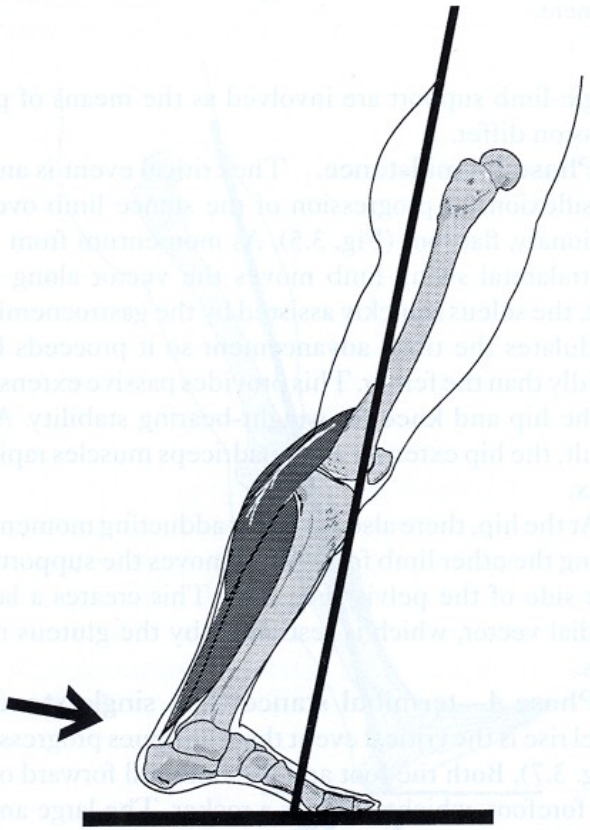
Mid-Stance

- GRF:
  - Weight line changes from posterior to anterior position at the knee and hip
- Joint Position:
  - Hip – flexion to extension
  - Knee – flexion to extension
  - Ankle – Neutral to dorsiflexion
- Active Muscles:
  - Hip Extensors stabilize trunk
- **Knee**
  - **Ensure full extension with no moments around the knee**
  - **When Geometric locking mechanism in place ensures stability**

Inman Term: *Mid-Stance*

Stance Phase – Terminal Stance

- Single Limb Support

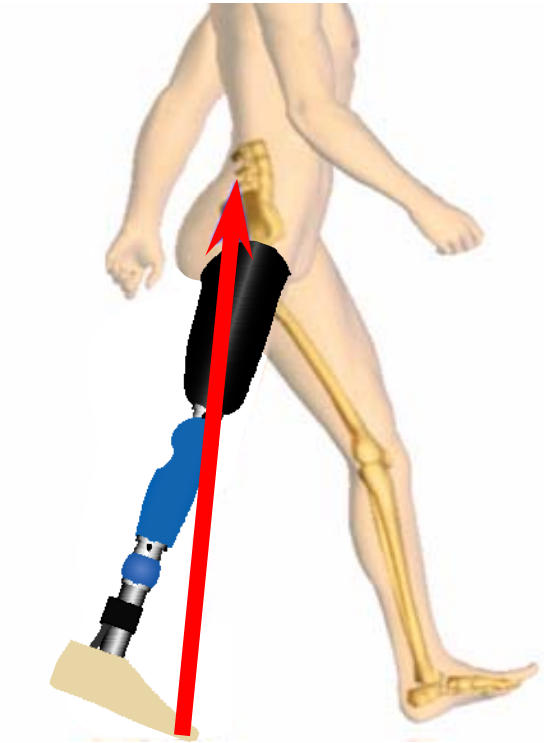


Terminal Stance

- Objective:
  - Forward trunk progression beyond the trailing limb
- Active Muscles:
  - Ankle plantar flexors

Inman Term: Heel-Off

Prosthetic Knee Stance Phase: *Terminal Stance*

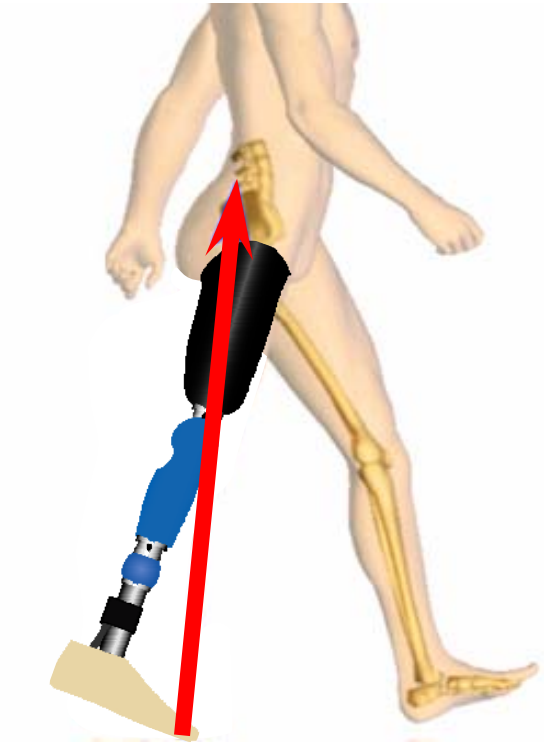


Terminal Stance

- GRF:
  - Posterior to Hip
  - Anterior to Knee and Ankle
- Joint Position:
  - Hip-Extended
  - Knee-Extended
  - Ankle-Rise & Dorsiflexed
- Active Muscles:
  - Proportional response of Px foot
- **All Knees:**
  - **Forefoot load to produce reduced effort to initiate swing**

Inman Term*: Heel-Off*

Prosthetic Knee Stance Phase: *Terminal Stance*



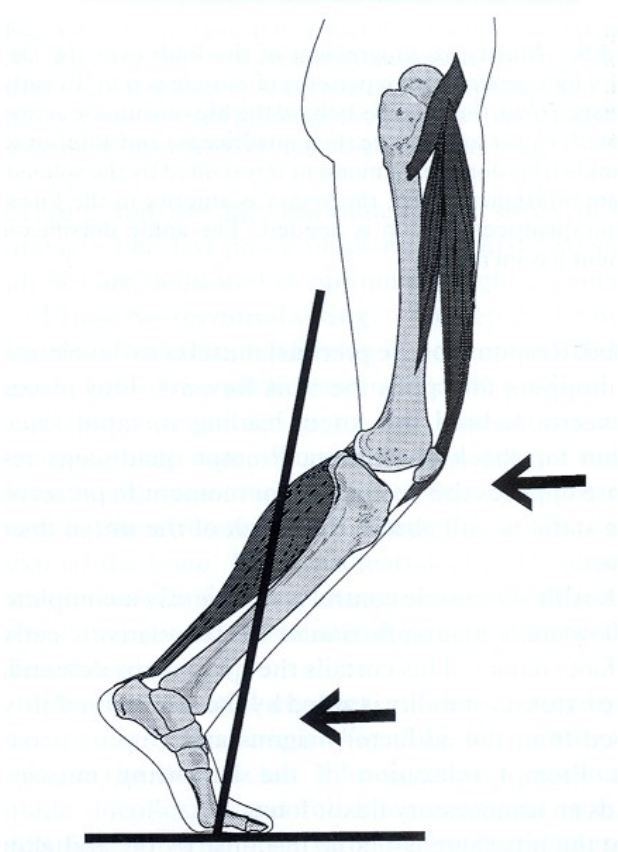
Terminal Stance

- GRF:
  - Posterior to Hip
  - Anterior to Knee and Ankle
- Joint Position:
  - Hip-Extended
  - Knee-Extended
  - Ankle-Rise & Dorsiflexed
- Active Muscles:
  - Proportional response of Px foot
- **Yielding Knee:**
  - **Knee in full extension with Toe load creating a hyperextension moment to switch from stance to swing mode**

Inman Term*: Heel-Off*

Stance Phase – Pre-Swing

- Single Limb Support

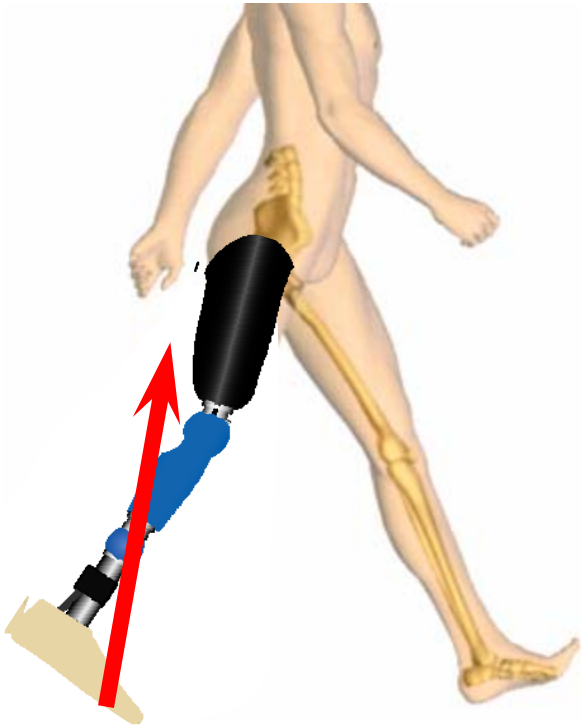


Pre-Swing

- Objective
  - Position limb for swing
  - Begin second period of double support
- Active Muscles:
  - Hip adductors
  - Knee extensors

Inman Term: Heel-Off/ Toe-Off

Prosthetic Knee Stance Phase: *Pre-Swing*



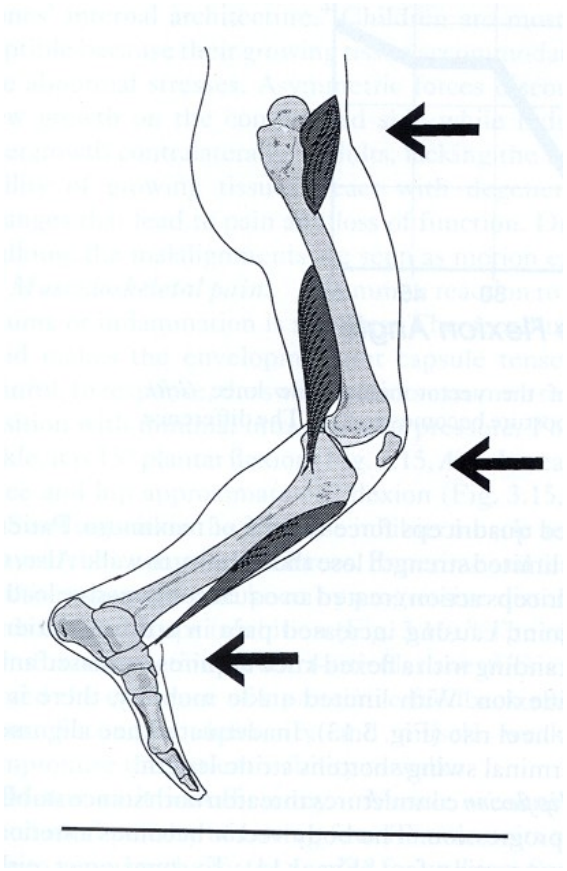
Pre-Swing

- GRF
  - Posterior to Hip
  - Posterior to Knee
  - Anterior to Ankle
- Joint Position:
  - Hip - neutral
  - Knee - flexed
  - Ankle – toe loaded
- Active Muscles:
  - Hip adductors
- **Knee:**
  - **Knee beginning to shift from full extension to flexion**
  - **Must ensure the appropriate toe loads have been applied to ensure that the knee releases into swing**

Inman Term: *Heel-Off/ Toe-Off*

Swing Phase – Initial Swing

- Limb Advancement

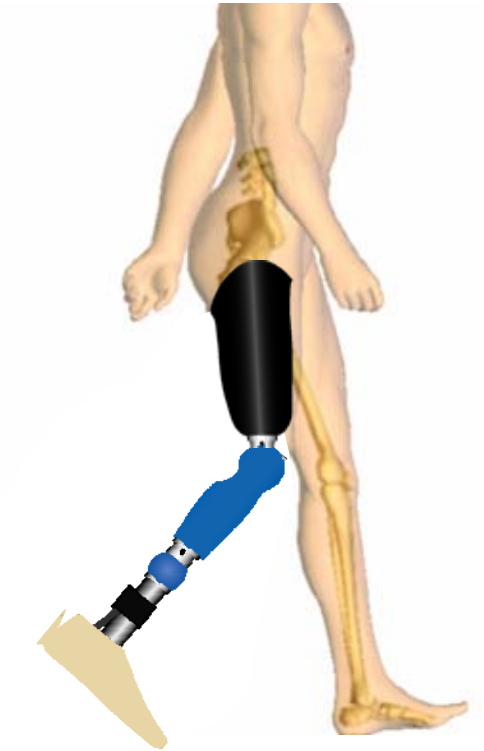


Initial Swing

- Objective:
  - Advance limb during contralateral single limb support.
  - Achieve optimal knee flexion (60°) for toe clearance
- Active Muscles:
  - Hip flexors
  - Knee flexors
  - Ankle dorsiflexors

Inman Term: Toe-Off

Prosthetic Knee Swing Phase: *Initial Swing*



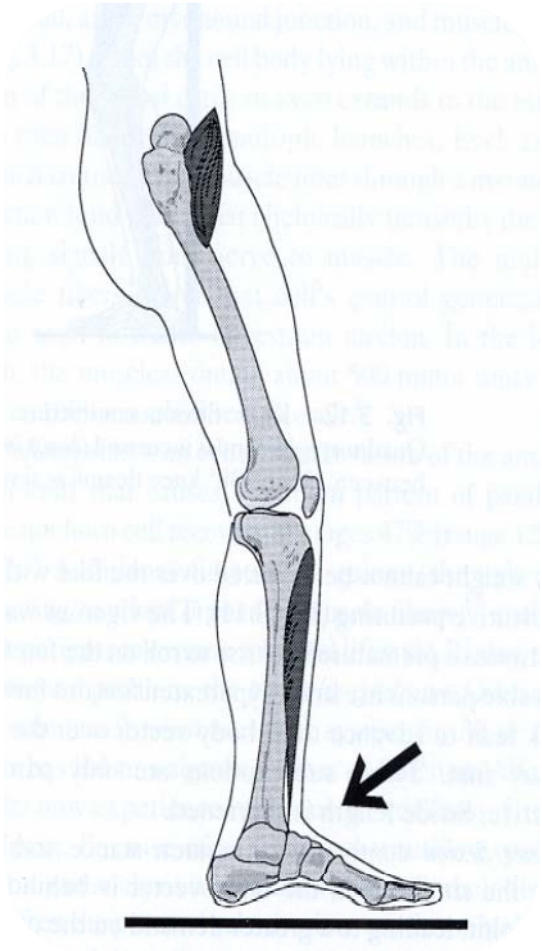
Initial Swing

- Gravity and Momentum
- *Goal:* Achieve optimal knee flexion (60°) for toe clearance
- Joint Position:
  - Hip & Knee-Flexed
- Active Muscles:
  - Hip flexors
- **All Knees:**
  - **Swing flexion resistance dependent upon unit type eg Hydraulic/Pnematic/Frictional**
  - **Looking to limit heel rise**
- **Polycentric Knee:**
  - **Shortens through the swing phase**

Inman Term*: Toe-Off*

Swing Phase – Mid Swing

- Limb Advancement

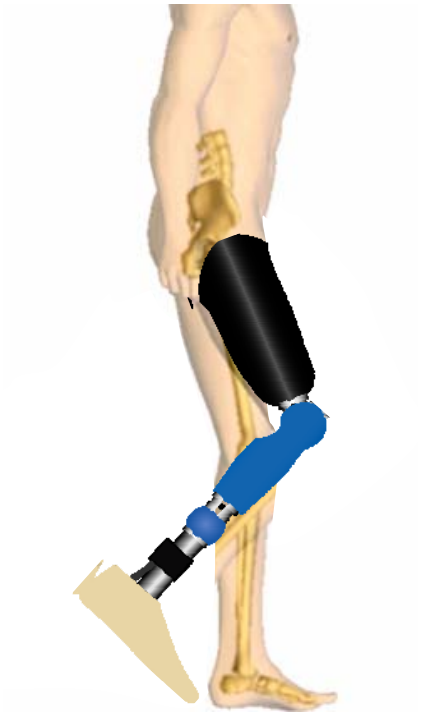


Mid Swing

- Objective:
  - Advance the limb during contralateral single limb support.
- Muscle activity:
  - Hip flexors
  - Dorsi flexors

Inman Term: Mid-Swing

Prosthetic Knee Swing Phase: *Mid-Swing*



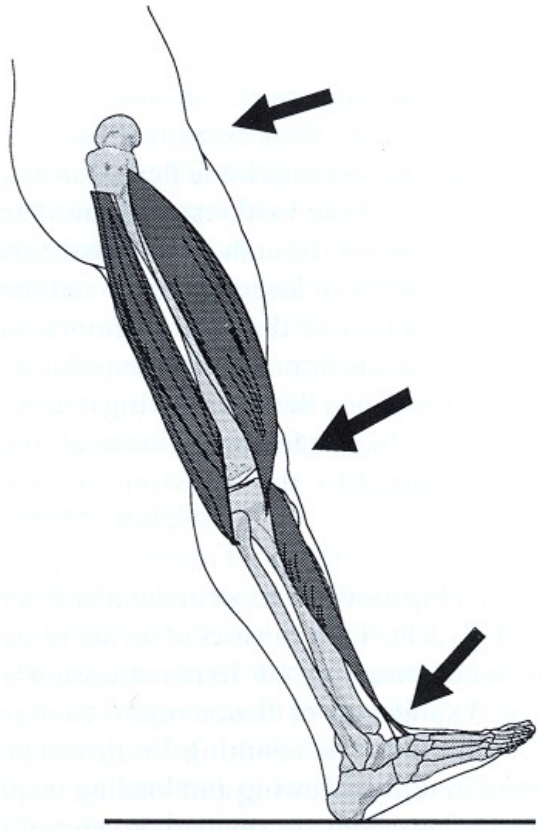
Mid-Swing

- Initial Swing provides momentum generation through muscular action for increased efficiency
- Muscular Activity:
  - Hip Flexors drive socket forward and flexes the knee
- **All Knees:**
  - **Swing flexion resistance dependent upon unit type eg Hydraulic/Pnematic/Frictional**
  - **Looking to reduce excessive heel rise**
  - **Make sure that the foot clears the ground**

Inman Term: *Mid-Swing*

Swing Phase – Terminal Swing

- Limb Advancement

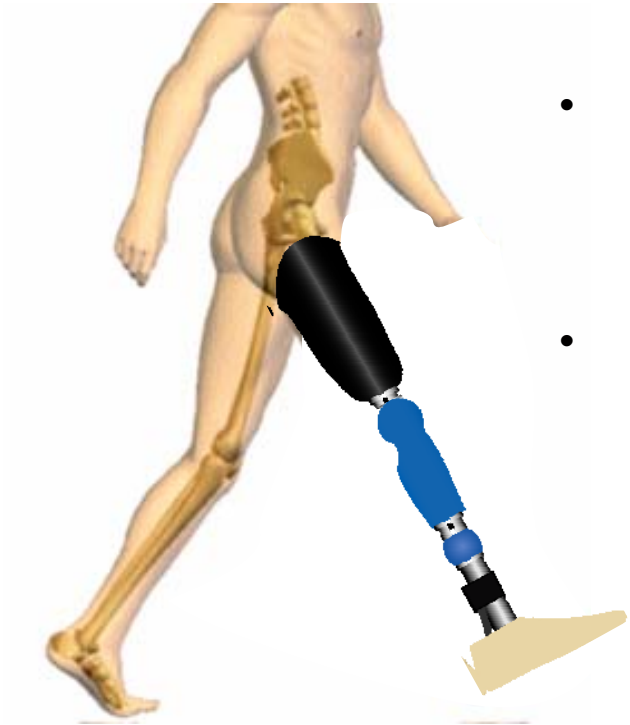


Terminal Swing

- Objective:
  - Preperation for stance and optimum weight acceptance
  - Still single limb support, which began with a vertical tibia and ends with the heel on the ground
- Muscle activity
  - Momentum and knee extensor action required to lift weight of tibia and foot for full extension
  - Knee flexors decelerate the hip

Inman Term: Deceleration

Prosthetic Knee Swing Phase: *Terminal Swing*



Terminal Swing

- Approach 30° hip flexion
- Momentum and hip flexion required to lift weight of prosthesis
- Muscular Activity:
  - Hip extensors slow advancement of thigh and therefore shin/foot
- **All Knees:**
  - **Smooth deceleration required to prevent terminal impact**
  - **Full extension to ensure we are ready to begin the cycle again!**

Inman Term*: Deceleration*

Knee Selection - Summary

- Prosthetic knee function is a continual compromise compared to the anatomical knee
- Good prioritization of desired functions based on voluntary control and rehabilitation goals will help in selecting the appropriate technology
- Stance control functions are critical to understanding mobility functions that can be achieved with a particular knee
- Prosthetic users need good education on device benefits, limitations, and how to utilize
- ***More advanced technology cannot replace rehab!!***

Practical Demonstration time

Part 2

With

Cathy Howells - Physiotherapist

Robert Paino - Mauch 136 User

John Price – Total Knee 2000 User

Össur Knee Systems

Matching technology to mobility goals

Who is the ideal Mauch® candidate?

Primary indications for use

- Amputation levels: Short (proximal 1/3) to long TF or KD, & bilateral
- Body Weight: 136kg
- Unlimited community ambulation & recreation sports

- **<u>Primary Mobility Priorities:</u>**
  - Level ground and uneven ground walking
  - Wide range of cadence variation
  - Frequent shallow and steep ramp descent
  - Frequent stair descent
  - Require special functions for other activities

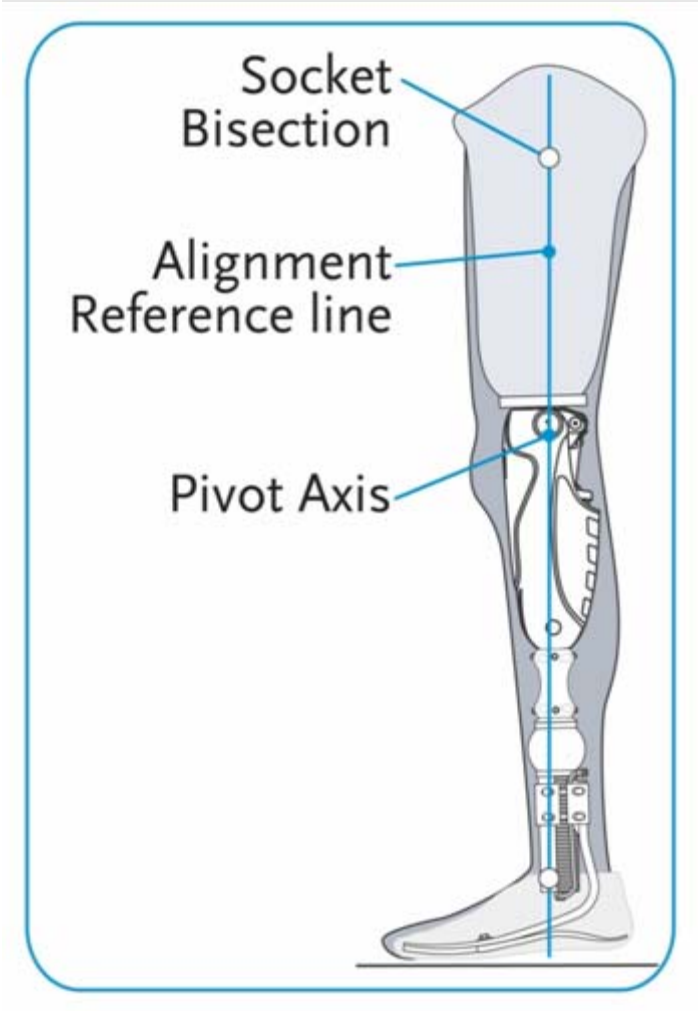
- **<u>Other Priorities Include:</u>**
  - Ease in sitting
  - High strength
  - Stumble control

Össur Knee Technology

Benefits & Limitations of Mauch®

- **Single Axis Hydraulic Swing and Stance Control:**
  - ***Benefits:***
    - Controlled and natural descent of stairs and ramps
    - Controlled support when moving to a seated position
    - Manual lock for extreme stability when needed
    - Swing only mode offers unlimited free motion for sports
    - Wide cadence variation
    - Provision of stumble control function
    - Heavy duty frame design
  - ***Limitations:***
    - Stability can be compromised on ramps, stairs, and uneven ground if the knee is hyperextended and loaded improperly – proper training and alignment is essential for good function
    - No stance flexion function
    - No swing phase shortening
    - More difficult to match knee center and to cosmetically finish

Alignment recommendation



- Position the socket so that the alignment reference line bisects the lateral wall of the socket and falls through or slightly posterior (5mm) to the knee bolt

Alignment

Reference line falls posterior to knee center

- Premature knee flexion may result
- User may feel unstable on the knee

Alignment

Reference line falls anterior to knee position

- Difficult to initiate knee flexion in pre-swing due to shortened toe lever
- Increases risk of stance control deactivation in early stance and on stairs and ramps

Stance activation

- Ground reaction force passes posterior to knee
- Piston is depressed into cylinder providing superior torque and support
- Primary use on ramps and steps and for sitting

Stance deactivation

- 1/10 second hyperextension
- Eliminates yielding stance so that swing resistance remains independently
- When properly aligned, little effort from hip flexors is required to initiate knee flexion

Who is the ideal TK candidate?

Primary indications for use

- Amputation levels: Hemi-pelvectomy to long TF or KD, & bilateral
- Body Weight: 100kg
- Limited to unlimited community ambulators

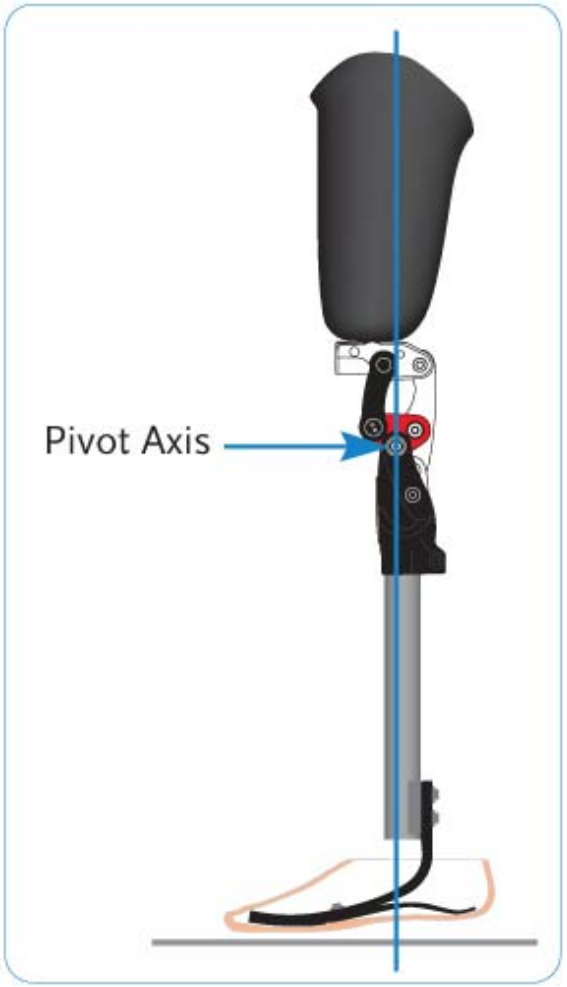
- **<u>Primary Mobility Priorities:</u>**
  - Level and uneven ground walking with ease and stability
  - Cadence variation
  - Shallow ramps ONLY (i.e. 5-7°)
  - Limited need for stair descent functions
- **<u>Other Priorities include:</u>**
  - Good range of motion for sitting and kneeling (160° flexion)
  - Good cosmetics – low build and slim profile

Össur Knee Technology

Benefits & Limitations of Total Knee

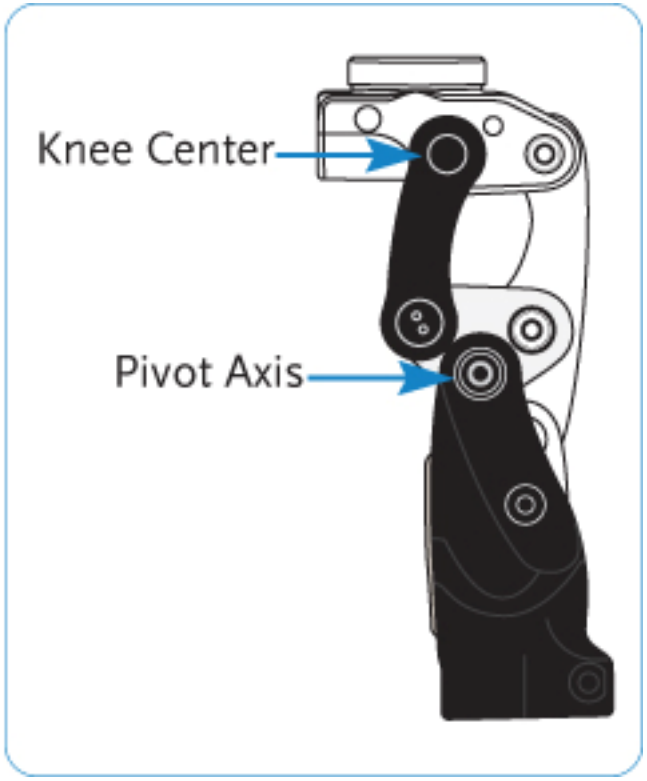
- **Polycentric with Geometric Lock**
  - ***Benefit:***
    - Knee locks in one position when loaded in full extension to provide better stability for the user during loading response
    - 15° of knee flexion available during loading response which mimics the movement of the intact limb during walking
    - Increased swing phase clearance (due to geometry of linkages)
    - Excellent matching of knee center for improved swing phase performance and cosmetic results for long amputations
  - ***Limitations:***
    - Limited ability to descend steps foot over foot
    - Must extend the knee and load the toe to sit – no support provided when moving to a seated position
    - No stability is provided unless the knee is extended prior to contact with the ground (awareness of foot, knee and limb position is critical)
    - No protection or support for the user in the case of a stumble

Total Knee
Alignment



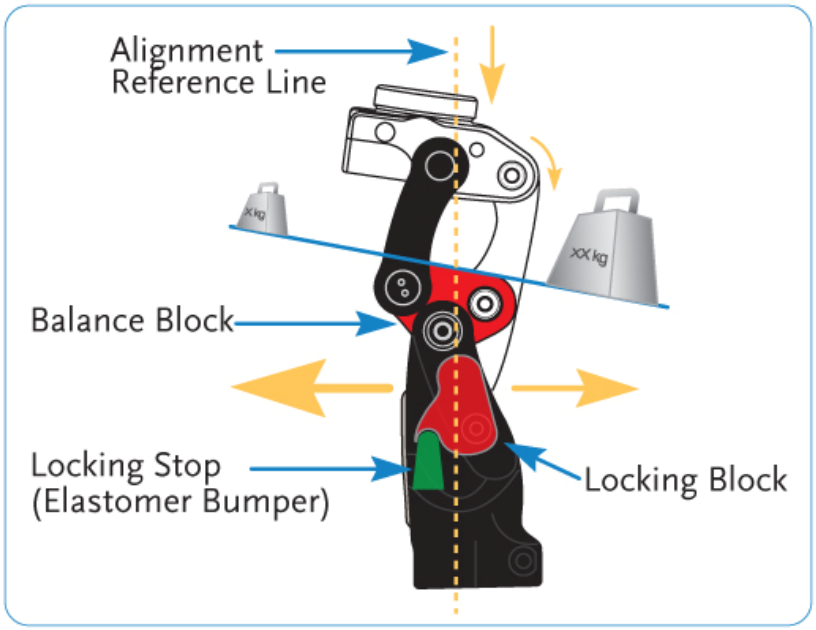
- Establish a vertical pylon
- Position socket so that the alignment reference line bisects the lateral wall of the socket and falls 0-5mm anterior to the pivot axis

Total Knee
Alignment



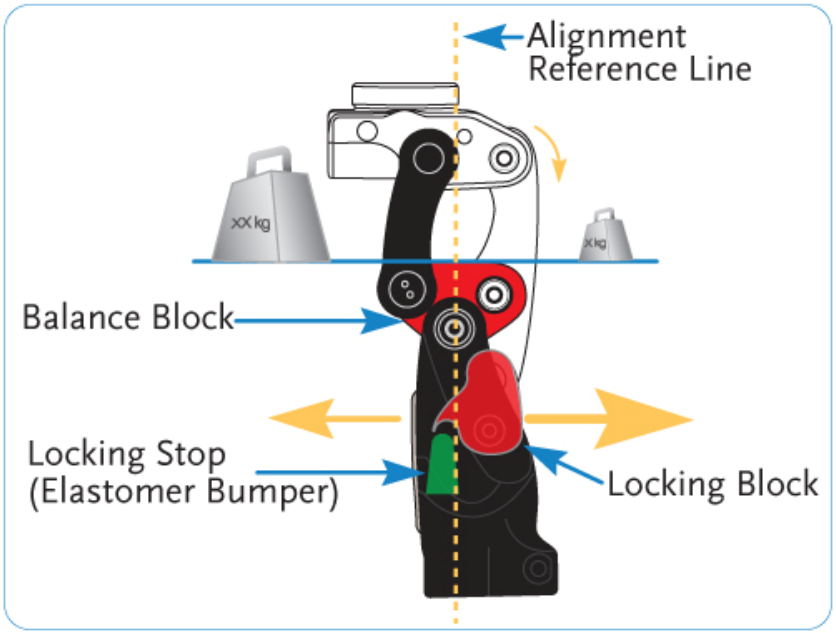
- The knee center reference is the most proximal anterior axis
- The pivot axis is the center axis of the balance block and ALWAYS the alignment reference for bench alignment

Geometric Lock
Activation



- Load applied posterior to pivot axis
  - Lock Activated
- Stance Flexion initiated
  - 15° Limit

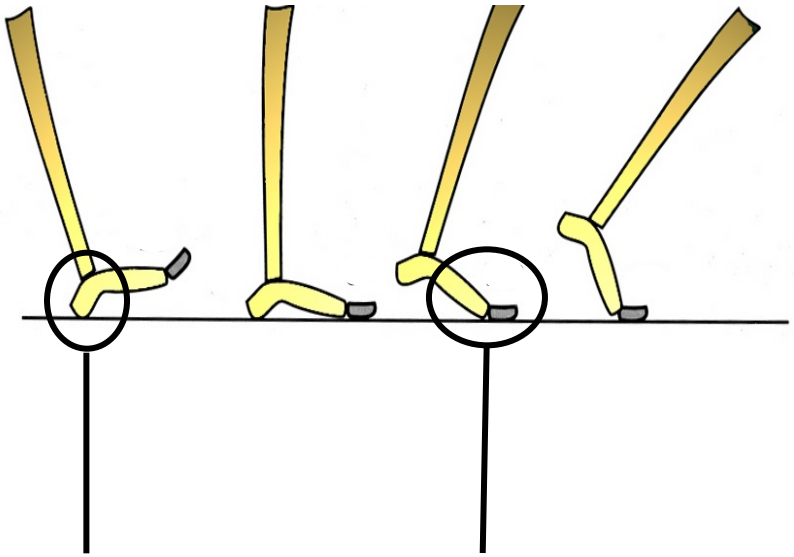
Geometric Lock
Deactivation



- Load applied anterior to pivot axis
  - Lock deactivated
- Knee to full extension
  - Easy initiation of flexion in Pre-Swing

Matching of foot and knee

Optimize overall performance



Heel and/or bumper stiffness

Keel length

Keel stiffness

- Foot selection can compliment or detract from optimal knee stability and performance
- **Key principles for Mauch® and Total Knee Systems:**
  - Proper alignment
  - Avoid soft heels and/or plantar flexion bumpers
  - Avoid soft or short keels
- **Pay special attention:**
  - SACH feet (soft heels)
  - Single-Axis feet (soft plantar-flexion bumpers)
  - Multi-Axis feet (soft bumpers and/or construction)

Thank you

ÖSSUR ACADEMY