Prosthetic Knees

Classification & Overview

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Objectives

Upon Completion of this unit, you will:

1. **Recall four systems for describing/classifying prosthetic knees**
2. **Understand and apply basic indications/contraindications to select the Best knee when given a patient/client scenario**
3. **Be able to appropriately describe, basic qualities of a prosthetic knee when presented with a photo, video or scenario**
4. **Be able to describe or recall how the position of the weight line, relative to the prosthetic knees center of rotation, will effect stability**
5. **Demonstrate an understanding of control versus stability by selecting an appropriate prosthetic knee given case scenarios**
6. **Recall elements that influence control**
7. **Recall elements that determine stability**

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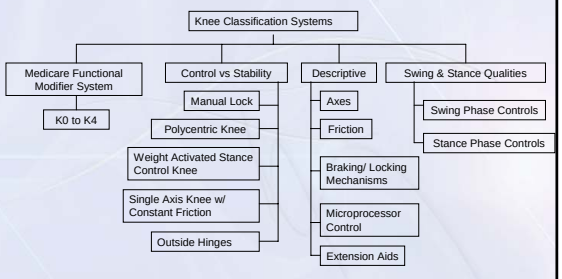
Prosthetic Knees



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Control versus Stability

- Volitional *Control* refers to the user's influence on the device
- *Stability* is, in a way, the device's influence on the user
  - It is an indication of how likely (or unlikely) a knee is to flex or buckle when an extended knee is desired

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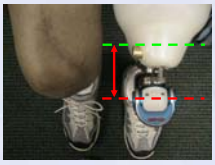
3 Aspects of Control

1. Residual Musculature (Force)
2. Residual Limb Length (Distance)
3. Motor Control



- Note the length of the Red arrow (left) vs the length of the Green arrow (right).
- The Red arrow is a longer distance from end of residual limb to knee center (KC) typical of a shorter to mid-length TF amputation. This will increase
  - **Distance between the limb and KC**
  - **Moment required to accelerate/decelerate the limb**
- Decreased control, proprioception and residual musculature are expected in the case at left, more so than in the case at right

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Control- Residual Musculature

Torque = Force x Distance

Force: from residual muscles

- How much *muscle* remains is effected by limb length
- Residual Musculature has varied qualities:
  - **strength, endurance, power, length tension ratio**

Consider:

- 70% vs 45% intact residual muscle
- 70% will yield more force = more torque

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Control- Residual Length

Torque = Force x Distance

- Distance = perpendicular distance from rotational center
  - Rotational center = hip joint
  - Perpendicular distance is residual femur length (lever arm)
- How much muscle remains is effected by *limb length*
- *Mathematically*, longer femur increases torque
- *Prosthetically*, other benefits as well:
  - More area for loading
  - If Knee Disarticulation (KD), end bearing as well &
  - Muscles fully intact

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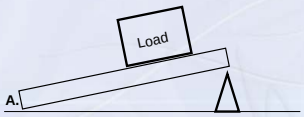
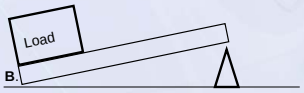
Limb Length



Case A- More like the knee disarticlation (KD) amputation. Mass is closer to the center of rotation (COR). Long lever arm in place. Control is probably better than shorter transfemoral (TF) limbs.



Case B- More like a short trans-femoral residual limb. Prosthetic mass is greater requiring more torque to rotate the system from a limb that is less capable of producing it.

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Control- Motor Control

- Motor control of the Residual Limb
- Etiology plays a role:
  - Traumatic vs vascular vs congenital
- Consider a given traumatic incident:
  - To what extent are neuromuscular connections compromised?
  - Will this effect volitional movement?
- Consider a Congenital Case:
  - Are all typical muscles present?
- Consider Vascular cases
  - Neuropathy? Extent?

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"Inherent" Stability

Based on:

- type, number & location of axes
- degree & type of friction
- Presence/ absence & adjustment of braking/locking mechanism
- microprocessor control
- extension aid

Said more simply…

Alignment of the knee

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"Inherent" Stability

1. type of prosthetic knee joint

2. alignment or position of the knee's COR relative to TKA/ weight line

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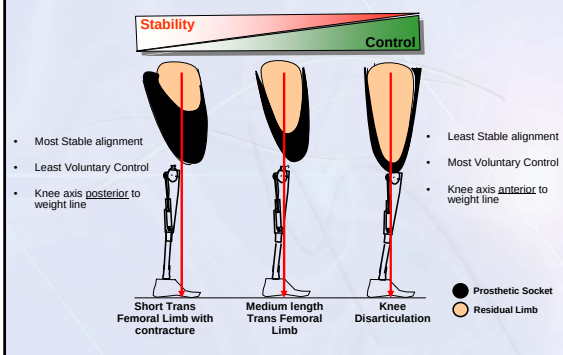
Stability from Alignment



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Knee Classification Systems

4 Systems

1. Medicare Functional Classification Levels
2. Stability vs. Control
3. Descriptive
4. Swing & Stance Qualities

Because the swing and stance operations of prosthetic knees may function completely separate of each other or be somewhat reliant upon one another, and due to the fact that hybrid knees exist, classifying them is extremely difficult.

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System 1

Medicare Functional Modifier System
"K" Scale/Score

K Level	Functional Description	Prosthetic Feet	Prosthetic Knees
K0	Non-ambulatory. Not a prosthetic candidate.	None	None
K1	Limited and unlimited household ambulation. Level surfaces. Fixed cadence. Transfers and therapeutic use.	Basic Feet: External Keel, SACH, Single Axis	Basic knees
K2	Limited community ambulation. Able to traverse low-level environmental barriers (curbs, ramps, stairs, uneven surfaces).	Multi-axial feet, Flexible Keel feet, Axial rotation (ankle) unit	
K3	Community ambulation. Variable cadence gait (or potential). Most environmental barriers.	Dynamic response feet	Fluid & Pneumatic knees
K4	Children. Those with Bilateral involvement. Active adult. Athletes. Exceeds basic use.	Any	Any

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Medicare System – System 1 Considerations

- Rules out "non-candidates"
- What is a "basic" prosthetic knee
  - Manual locking?
  - Weight activated stance control?
  - Single axis?
    - **Most computerized knees are single axis**
- Rules in "fluid" friction at the K3 level
- More for classification of functional level
- Reimbursement may be the determinant
- Consider the fact that the VA system & DOD do not typically follow this system

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System 2
Stability versus Control

1. Manual Locking Knee
2. Polycentric Knee
3. Weight Activated Stance Control Knee
4. Single Axis Knee/ Constant Friction
5. Outside Hinges

#1 is Most stable and offers/requires the Least Voluntary Control

#5 is Most unstable and offers/requires the Most Voluntary Control

What scenario indicates #1, #2, #3, etc.??

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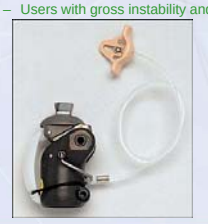
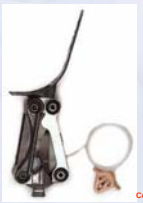
Manual Locking Knee

- Maximum Stability/Least voluntary control
- Contraindicated when anything else will work
- Indicated for
  - low level bilateral users
  - blind users
  - Users with gross instability and weakness





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Manual Locking Knee

- Pull switch to deactivate knee extension lock
- Must have some ***hand dexterity or assistance***

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Manual Locking Knee

- I.T.→ Floor (measurement): must be shorter than sound limb to clear swing phase.
- Poor gait quality; hip hiking, circumduction
- What if bilateral?
  - Manual lock on non-dominant side? Bilateral Manual locks?

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Caveats of Manual Locking Knees

- All bilateral prosthetic knee users often have at least one knee that locks
- A locking feature may be desired with a high activity user:
  - Example: a baggage handler may desire a lock feature to decrease mental effort when lifting, side bending, etc.
  - Microprocessor knees, Mauch Knees have lock features

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Polycentric Knee

- Knee Center of Rotation (COR) is described as instantaneous COR (ICOR) because it relocates throughout the ROM
- Polycentric axis allows the leg to effectively shorten for swing
- 2 separate designs for ***KD*** and short ***TF*** (functional opposites) (*T=FD*)
- KD will have KC discrepancy and need shorter pylon for swing clearance & cosmesis
- Short TF will possibly need assistance clearing the foot in swing, increased stability, ease of initiating flexion & locking

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Polycentric Knee

Highly Stable in extension due to ICOR's
- Posterior position relative to weight line

Easy to initiate flexion
- When ICOR is close to hip joint
  - **Much more proximal than knee's physical location**

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Polycentric Knee

Anterior

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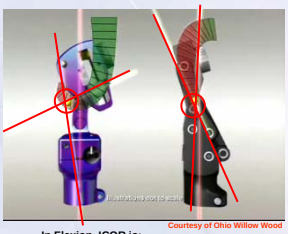
Posterior



Courtesy of Ohio Willow Wood

In Extension: ICOR is:

1. **Posterior to knee & hip joints: HIGHLY STABLE**
2. **Proximal to knee's physical location: Easy to Flex**

In Flexion, ICOR is:

1. **In close proximity to the weight line: HIGHLY UNSTABLE**
2. **Close to knee's physical location: Decreased Control**

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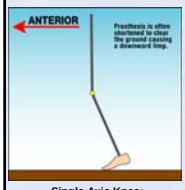
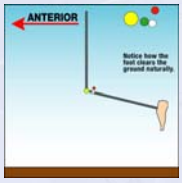
Polycentric Knee

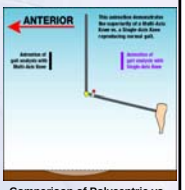
- Swing clearance: shortening; sketch/photo



Single Axis Knee:
Stubbing toe during swing



Polycentric Knee:
Clearing toe during Swing as leg effectively shortens



Comparison of Polycentric vs Single Axis knee

Animations from www.daw-usa.com

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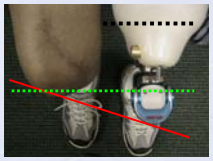
Polycentric Knee



Notice that this single axis knee causes the prosthesis to extend far beyond the sound side (red lines). The ideal position would be symmetric to the sound side (green lines).

Notice the knee center of this person with a knee disarticulation. Knee Center is only slightly beyond the sound limb due to the polycentric knee.

The dashed black lines represent the approximate location of the end of the residual limbs. If a single axis knee was used in the KD case (right), knee center would be much farther distally positioned than it already is.

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Weight Activated Stance Control

- Referred to as "safety knee"-
  - ***not*** a good idea
  - May give false ideas about knee's abilities
- Indicated for single speed ambulators (primarily K2)
- During stance, if the knee is flexed < 10-15°, the brake is engaged and the knee cannot flex or buckle
- Contraindicated for bilaterally involved patients
  - unable to sit because knee(s) will not flex when under load

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Weight Activated Stance Control

- Likely result in gait deviations;
  - hip hiking, circumduction
  - Must unload to flex for swing
- Are all polycentric knees more stable than weight activated stance control knees?
  - No, the versions for knee disarticulation are inherently unstable as voluntary control is likely good

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Weight Activated Stance Control

Note the following gait deviations in this case with use of the weight activated stance control knee:

- Hip Hiking
- Circumduction

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Single Axis Constant Friction

- Very basic in design
- Indicated in pediatric cases; durable, light
- Not too many available presently-evolution

Courtesy of Ossur

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Single Axis Constant Friction

Several knees are Single axis but offer ***variable friction***:

Examples:

- Microprocessor knees
- SNS units in a single axis cage/frame
- Pneumatic units

Courtesy of Ossur

Courtesy of Otto Bock

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Single Axis Constant Friction

Some are predominantly single axis but offer stance flexion through an additional axis:

Example:

Courtesy ofEndolite/Blatchford

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Outside Hinges

- Primarily for use with KD cases
- Traditionally with leather socket & exoskeletal shin
- Could be used with plastic or laminated interfaces
- May be used with short or unstable trans-tibial limbs as joint & corset design

Leather, lace-up socket for knee disarticulation

Courtesy of Tom Karolewski, CP from Northwestern University

Leather, lace-up socket with auxiliary suspension strap for knee disarticulation

Unknown Source

Leather thigh lacer with outside hinges for joint & corset design trans-tibial prosthesis

Courtesy of Tom Karolewski, CP from Northwestern University

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System 2

Stability versus Control
Considerations: Benefits/Drawbacks

- ✓ Provides framework of indications/contraindications
- ✓ Delivers promise of hierarchical order of stability vs control
- ☒ Not fully descriptive
- ☒ Established hierarchy has exception
- ☒ Does not neatly fit into Medicare's description

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System 3
Descriptive Method

1. ***Axes***
2. ***Friction***
3. ***Braking or Locking Mechanisms***
4. ***Microprocessor Control***
5. ***Extension Aids***

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Descriptive Classifications with Subclasses

- ***Axes***
  - ***Polycentric***
  - ***Single Axis***
    - *Modular/Endoskeletal*
      - ***Knee cage***
      - ***stand alone unit***
    - *Exoskeletal*
    - *Outside Hinges*


Courtesy of Ossur


Courtesy of Ossur

- ***Friction***
  - ***Fluid***
    - *Hydraulic*
    - *Pneumatic*
  - ***Sliding***
    - *Constant*
    - *Variable*

- ***Braking or Locking Mechanisms***
  - ***Manual Locking***
  - ***Weight Activated Stance Control***
  - ***Geometric Lock***


Courtesy of Otto Bock


Courtesy of Ossur

- ***Microprocessor Control***
- ***Extension Aids***
  - ***Internal***
  - ***External***


Courtesy of Ohio Willow Wood

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Axes

- The number of loci
  - 1
  - More?


Courtesy of Otto Bock


Courtesy of Ossur


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Axes

Polycentric
- → Endoskeletal/ Modular
- → Exoskeletal

Single Axis
- Modular/Endoskeletal
  - → Knee cage
  - → stand alone unit
- → Exoskeletal
- → Outside Hinges

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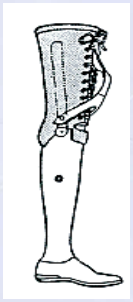
Friction



No Friction

Maximal Friction

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Friction

– *Fluid*
- *Hydraulic*
- *Pneumatic*

Hydraulic, Fluid Friction

– *Sliding*
- *Constant*
- *Variable*

Constant, Sliding Friction (Left)
Pneumatic, Fluid Friction (Right)

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Braking or Locking Mechanisms

- **Manual Locking**
- **Weight Activated Stance Control**
- **Geometric Lock**

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Braking or Locking Mechanisms

Extremes of Manual Locking Knees

Manual locking knee from Otto Bock

Mauch SNS Knee with Hydraulic, Fluid friction that has a manual lock feature

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Braking or Locking Mechanisms

Weight Activated Stance Control

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Braking or Locking Mechanisms

Geometric Lock

Example: Ossur's Total Knee (4 versions including HD and pediatric)

- Terminal Impact is expected to engage lock prior to HS
- Friction (3 options): hydraulic, polymer, none
- 3 hydraulic adjustments with fluid friction
- 2 mechanical adjustments (ext assist and stance flexion)

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Microprocessor Control

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Microprocessor Control

- Considerations:
  - Sampling rate
    - **What data is sampled**
  - Swing control only
  - Stance & Swing control
  - Friction medium (M.R., hydraulic)
  - Axes
  - Modes
    - **Is the default mode safe mode or free swing mode?**
  - Mass
  - Adjustment (hard connection, remote)
  - Charging time
  - Replaceable or rechargeable battery(ies)
  - Candidates
  - Aids with flexion or extension or both

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Extension Aids

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Extension Aids

- ***Internal***
- ***External***

Internally behind the yellow stance flexion bumper. It is a spring/cable mechanism.

Externally placed in this unit. As the knee extends from a flexed position, the aid accelerates the shin's rate of extension.

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System 4

Swing and Stance Qualities (Wilson)

- Schematic breakdown with descriptive categorization
- Breaks knees as a category into
  - Stance controls
  - Swing controls
- Then within each subcategory, further subdivides into
  - Type of resistance (swing)
  - Type of stabilizing quality (stance)

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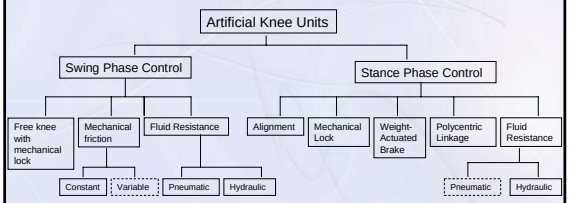
System 4
Swing and Stance Qualities (Wilson)



Note: Items in dashed boxes do not exist

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System 4
Swing and Stance Qualities (Wilson)
Considerations: Benefits/Drawbacks

- ✓ Provides a conceptual framework easy to understand
- ✓ Simplifies a complex concept
- ✓ Clearly differentiates swing from stance
- ☒ Dated
- ☒ Does not account for new fluid mediums
- ☒ Magnetorheologic fluids
- ☒ Must classify microprocessor control into its respective medium
- ☒ E.g. hydraulic
- ☒ May be too simplistic

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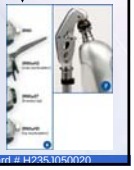
Missing from all Methods:

- Swing and Stance Control, Swing only
  - Probably separated out best by Wilson's Scheme
- Where does a polycentric knee with manual lock fit in?
- Stance Flexion
- Proximal & Distal Attachment Options
- Available ROM
- Weight & Activity Level Categories
- Microprocessor Sampling Rates
- Recommended Alignment
- What about the knee joints on a Joint & Corset Transtibial prosthesis?



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