C-Leg 4 Trainer certification

Biomechanical influence of prosthetic feet V 1.1

Academy (19pt)

Biomechanical influence of prosthetic feet

Key features of a prosthetic foot

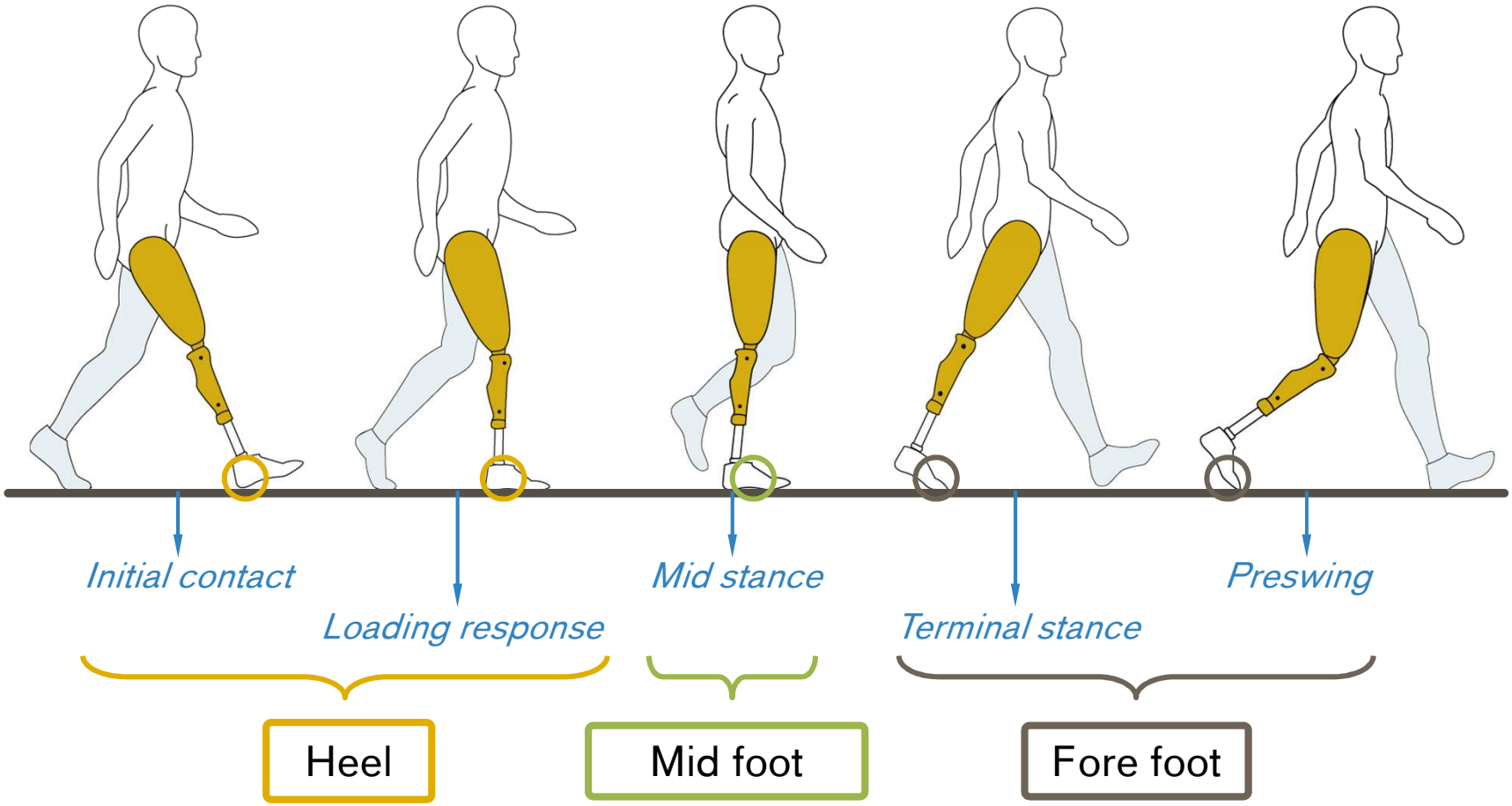
The following **four** fundamental biomechanical features should be reproduced by a prosthetic foot:

- Restoration of base of support while standing and walking
- Load transmission of the foot between body and ground
- Sensitive controlled torque generation of the foot for the movement of the entire body
- Possibility of reducing the load onto the skeleton and influencing the forces and moments onto adjacent joints

Source: Blumentritt S, HW Scherer, U Wellershaus. Biomechanisch-ganganalytische Bewertung von Prothesenfüßen, Med. Orth. Tech. 1994;114:287-292.

Biomechanical influence of prosthetic feet

Important sections of a prosthetic foot



Biomechanical influence of prosthetic feet

Selection of available feet for the Genium

1C60-63 Triton

1C40 C-Walk

1E56 Axtion

1E57 LoRider

1C30/31 Trias/+

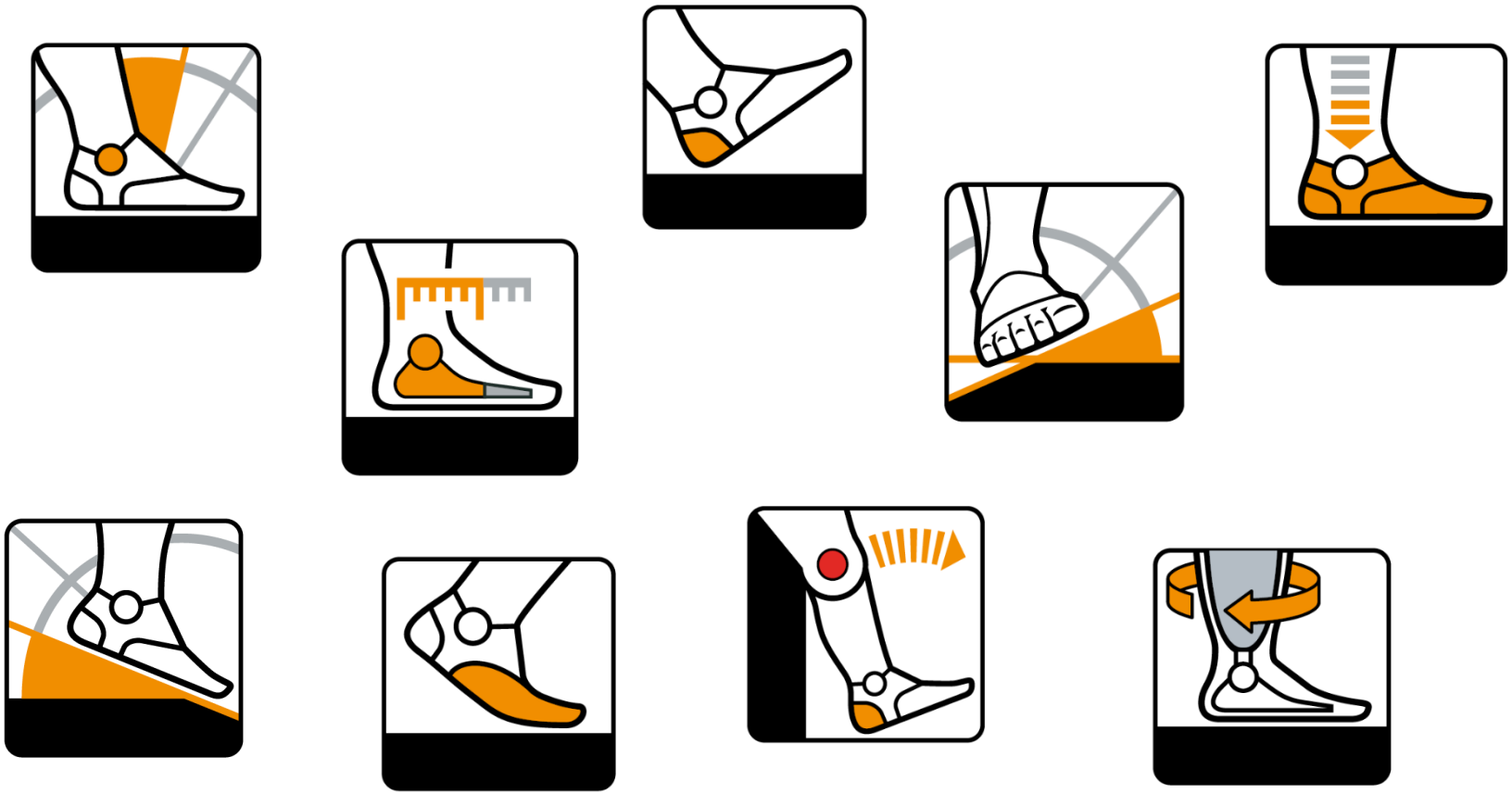
1D35 Dynamic Motion

1M10 Adjust

How can we choose the „right“ foot for the amputee?

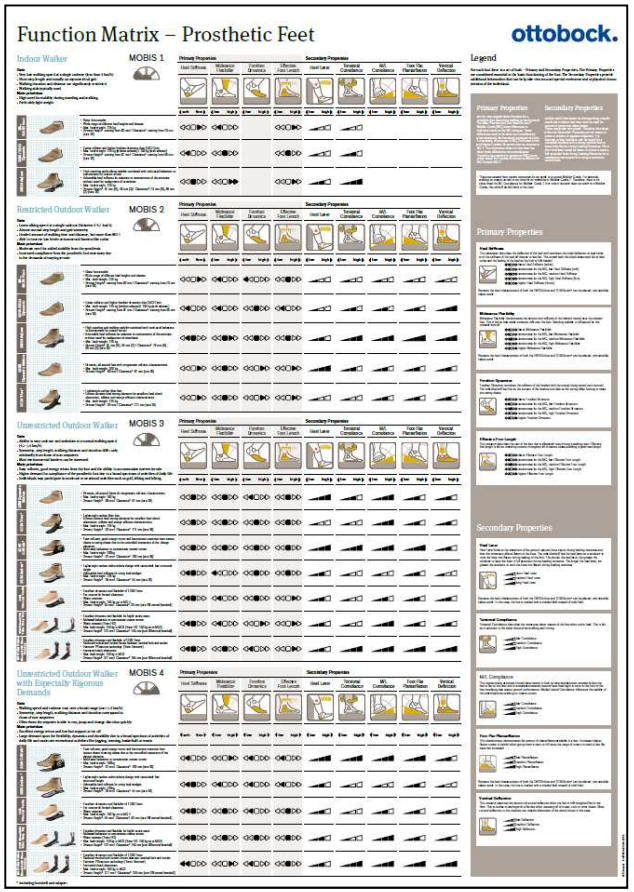
Biomechanical influence of prosthetic feet

Function matrix – Classification aid for OB feet



Biomechanical influence of prosthetic feet

Function matrix – Classification aid for OB feet

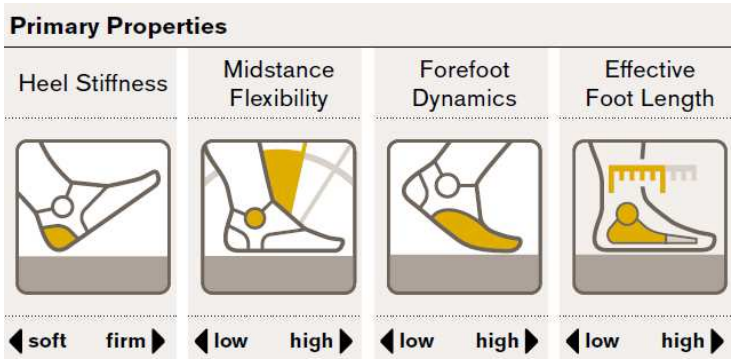


- Overview of the characteristics of Ottobock feet
- Every foot is described by different criteria, e.g.:
  - Heel stiffness
  - Forefoot dynamics
  - Length of the heel lever
  - Flexibility in mid stance phase
- Order number 646F307=EN-02-1005

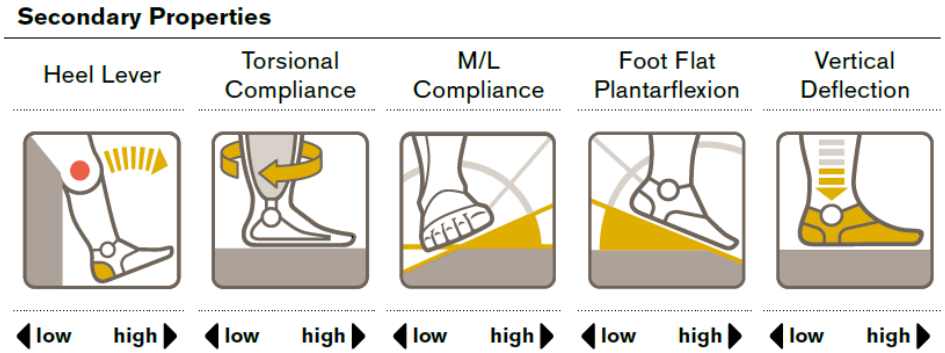
Biomechanical influence of prosthetic feet

Function matrix – Structure

- Divided in primary and secondary properties
- Basic explanation of the different foot functions
- Characteristics are described in **relation to the MOBIS level**



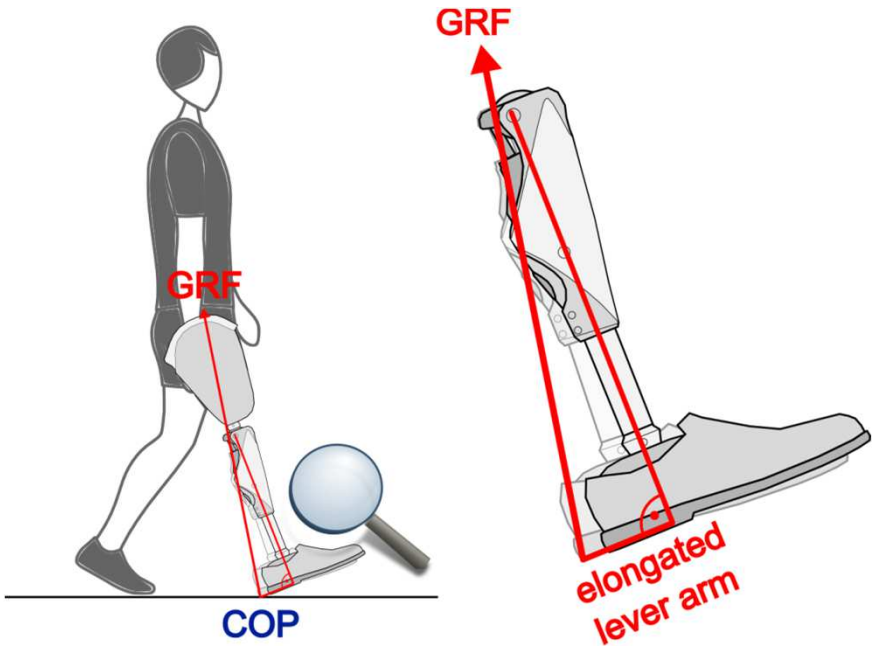
Walking on level ground



Individual needs of the amputee

Biomechanical influence of prosthetic feet

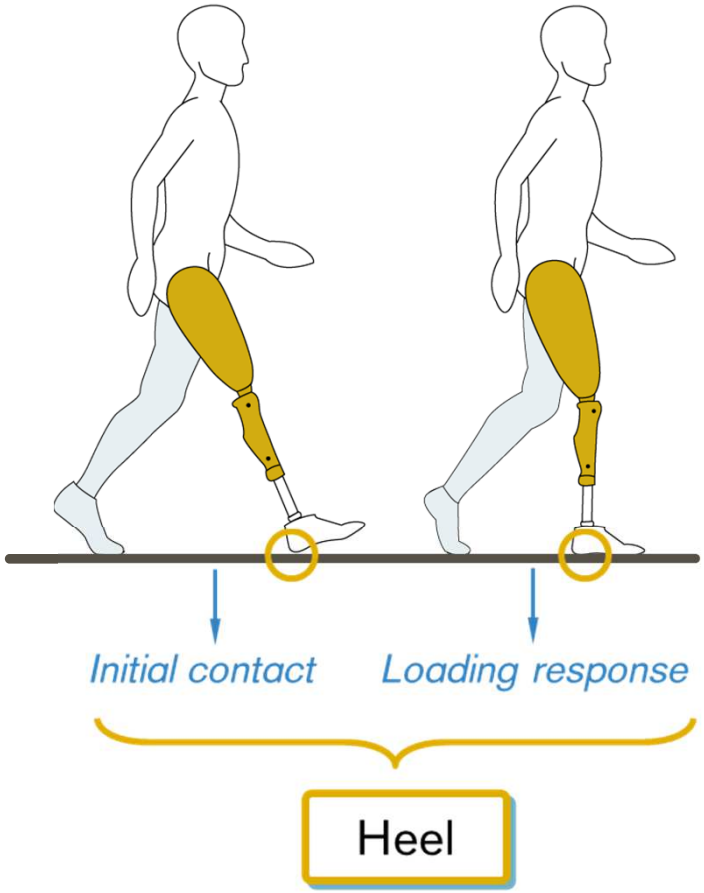
Influence of the foot position onto the dynamics



- The knee flexion support and forward momentum while load bearing is strongly influenced by the heel lever (starting point defined by bench alignment)
- The knee extension support starting with mid stance is strongly influenced by the forefoot lever
- If the foot is pushed posteriorly, the heel lever is extended and the toe lever is shortened (and vice versa)

Biomechanical influence of prosthetic feet

Different tasks at different times



The main features are…

- Accept body's weight
- Shock absorption
- Move forward (with COM)

Important foot behaviors are…

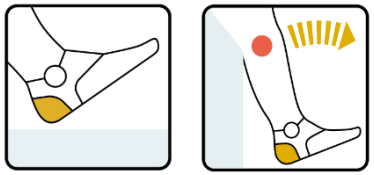
- Heel stiffness (softness and comfort at first weight bearing)
- Length of heel lever
- Rapidity of shortening heel lever

Biomechanical influence of prosthetic feet

Facts about the heel of a prosthetic foot

- **Heel stiffness** is something which does not change and is independent from the foot position

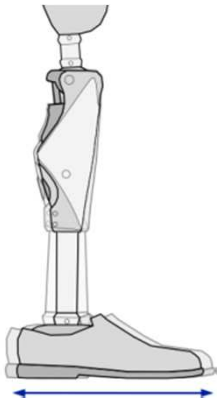
- **Length of heel lever** is something which can be influenced by the position of the foot



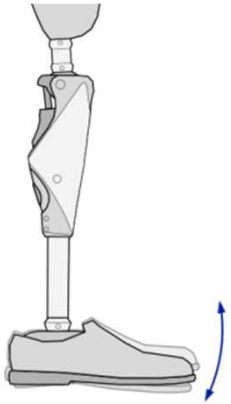
- Influence on knee flexion behavior and forward momentum can be influenced by changing stiffness **and** position of the foot

Biomechanical influence of prosthetic feet

How can the CPO influence the heel behavior?



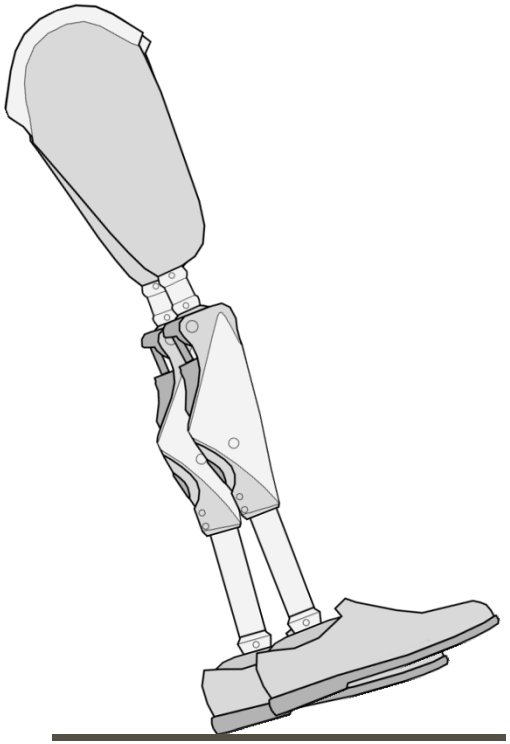
- Shifting the foot:
  - Shifting forward → shortens heel lever
  - Shifting backward → elongates heel lever
  - Influences the initial aggressiveness during stance flexion



- Changing flexion of the foot:
  - PF → reducing time on heel (shorter knee flexing effect!)
  - DF → increasing time on heel (longer knee flexing effect!)
  - **Does not** influence the aggressiveness

Biomechanical influence of prosthetic feet

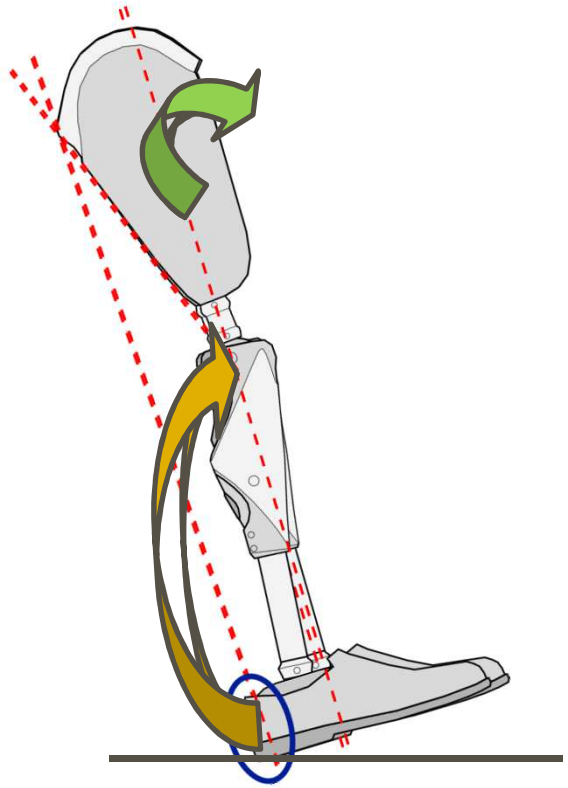
Adapting heel lever – For AKs



- A compromise between passiveness and aggressiveness must be found
- The compromise is set by the bench alignment but can be changed (via heel lever) by the CPO depending on knee behavior and hip extension capability of the user
- The user is only be able to influence the position of the foot by changing the step length (= compensation movement)

Biomechanical influence of prosthetic feet

Example: Elongating heel lever

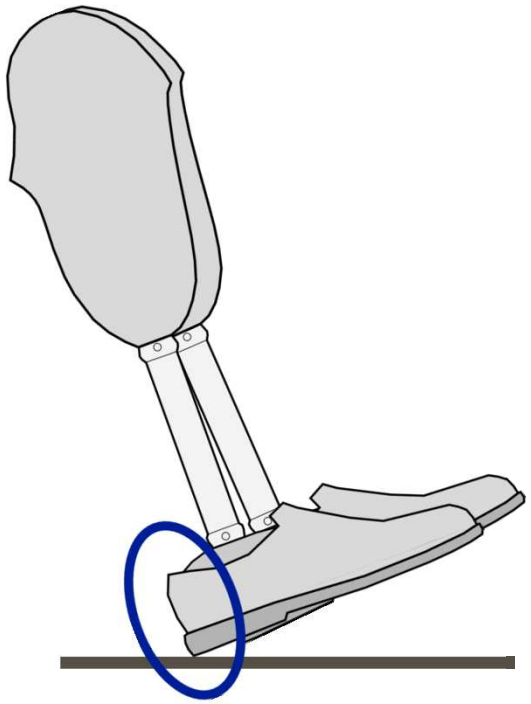


- When the foot is shifted backwards the influence on knee flexion and forward momentum will be stronger

- This can help to overcome the prosthesis easier **if** :
  - the prosthetic knee provides sufficient stance phase stability (e.g. Genium, 3R60, 3R80)
  - the user has powerful enough hip extensors to compensate the flexion tendency of the knee
  - the user wants to walk fast the whole time

Biomechanical influence of prosthetic feet

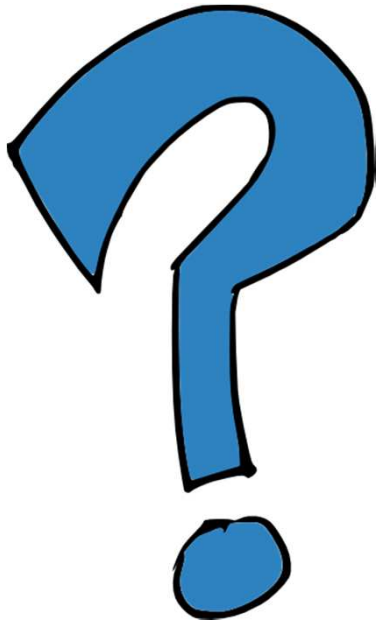
Adapting heel lever – For BKs

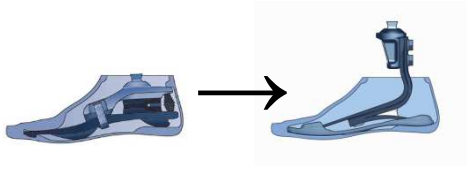


- Also for BKs a compromise between passiveness and aggressiveness must be found
- The **user is able to** (most likely unconsciously) …
  - elongate the heel lever and increase forward momentum via higher knee flexion angle
  - shorten the heel lever and decrease forward momentum via less knee flexion angle (effects on shock absorbance?)

Biomechanical influence of prosthetic feet

Influence of the foot onto the dynamics

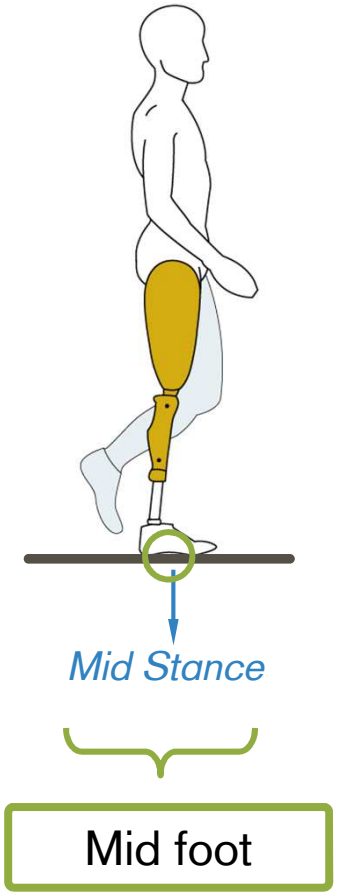




- Which possibility does the CPO have when there is too little knee flexion moment at heel strike?
  - Shifting foot posteriorly
  - Choose a foot with higher heel stiffness
  - (DF foot → mind static situation!)
- Which possibility does the CPO have when there is too much knee flexion moment at heel strike?
  - Shifting foot anteriorly
  - Choose a foot with softer heel stiffness
  - (PF foot → mind static situation!)

Biomechanical influence of prosthetic feet

Different tasks at different times



The main features are…

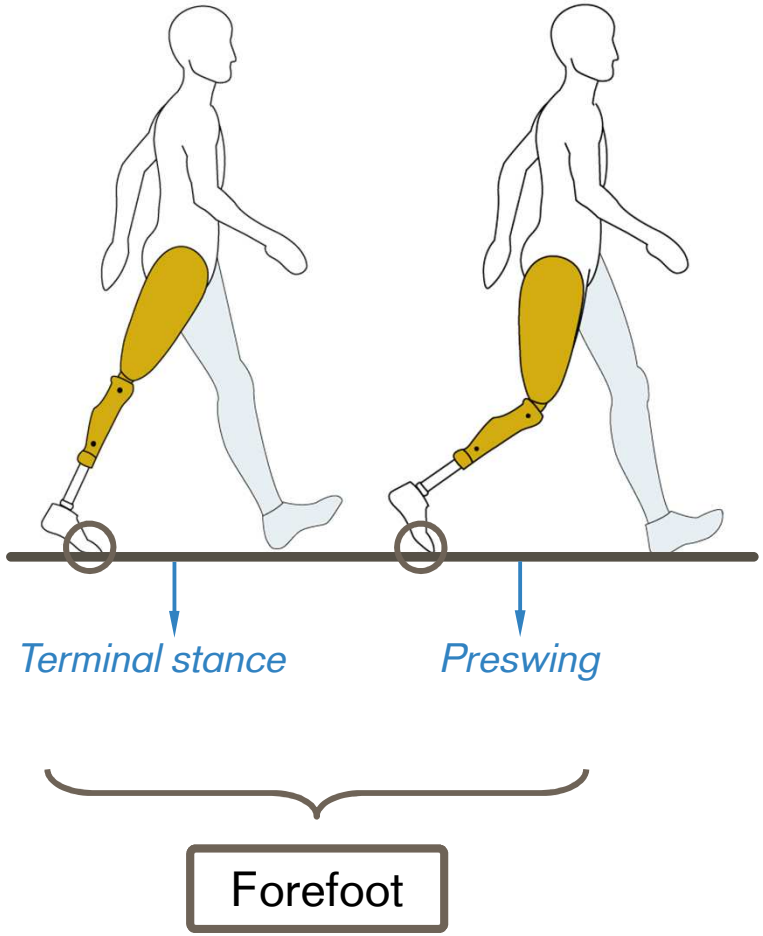
- Range of motion where the foot is standing flat on the floor
- Moments change direction (PF -> DF)

Important foot behaviors are…

- Transportation of the COP depending on the MG
- Degressive, linear, progressive behavior
- ROM (DF-angle before foot leaves the floor)

Biomechanical influence of prosthetic feet

Different tasks at different times



The main features are…

- Heel leaves the ground
- ↑ DF-moment at the end of the stance phase
- During preswing the foot returns from DF to PF

Important foot behaviors are…

- Support the body's weight while COM moves forward
- Stiffness / effective length of the (fore)foot
- Influence on swing initiation

Biomechanical influence of prosthetic feet

Typical forefoot characteristics

There are two typical characteristics:

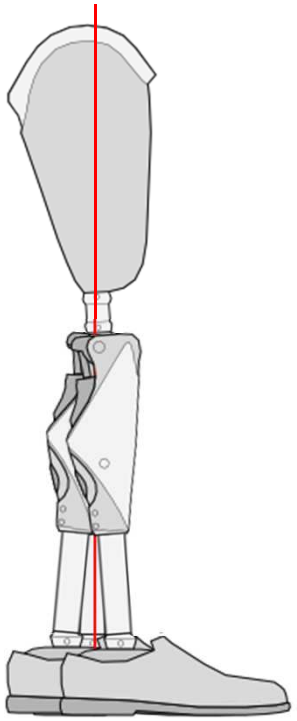
1. Higher deflection with later springy energy return
2. Less deflection but therefore the foot provides stability for the COM (step length!)

Feet which deflect and store energy (e.g. 1C30, 1C40) can lead to higher knee flexion angles…

- Helpful for slow walking speeds
- Helpful for amputees with short residual limbs (less energy cost)

Biomechanical influence of prosthetic feet

Influence of heel position onto the forefoot



- Shifting the foot posterior…
  - ↓ effective forefoot length
  - ↓ stability at terminal stance
  - ↓ the step range in front
  - Helps with preswing initiation

- Shifting the foot anterior …
  - ↑ effective forefoot length
  - ↑ stability at terminal stance
  - ↑ the step range in front
  - Hardens preswing initiation

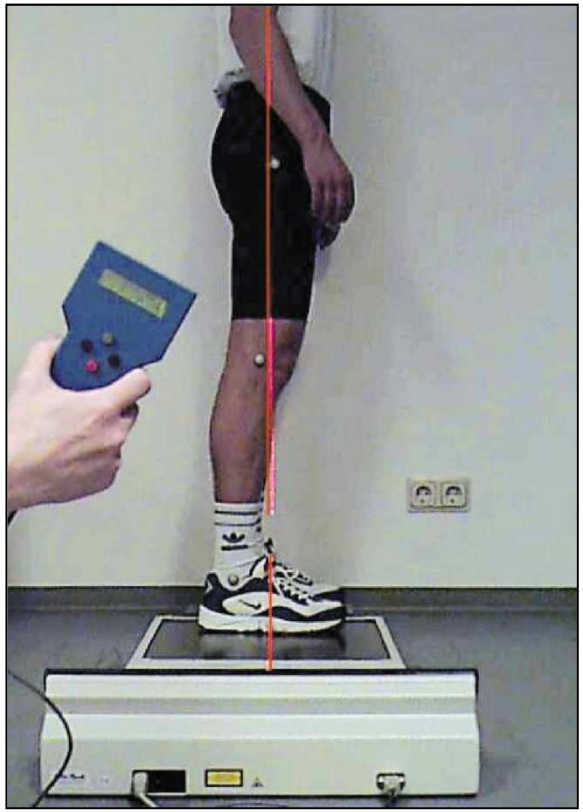
Biomechanical influence of prosthetic feet

Joint position (centre of rotation) of a prosthetic foot

- The anatomical centre of rotation leads to a constant DF moment
- This is compensated for physiologically by the calve muscles
- Normal prosthetic feet don‘t offer this kind of physiological control
- Copying anatomy **isn‘t always** the best way
- A repositioning of the ankle joint into the position of the load line annihilates the preexisting moment situation

Biomechanical influence of prosthetic feet

Stability of COP



- With most prosthetic feet the centre of rotation **is placed** at the anatomical position
- During shifting of weight the load line is moving back and forth → this causes an imbalance during standing
- This imbalance can lead to negative effects regarding knee stability
- The influence depends on the prosthetic foot and can be evaluated with the L.A.S.A.R posture (the CPO should check the knee stability during weight bearing)

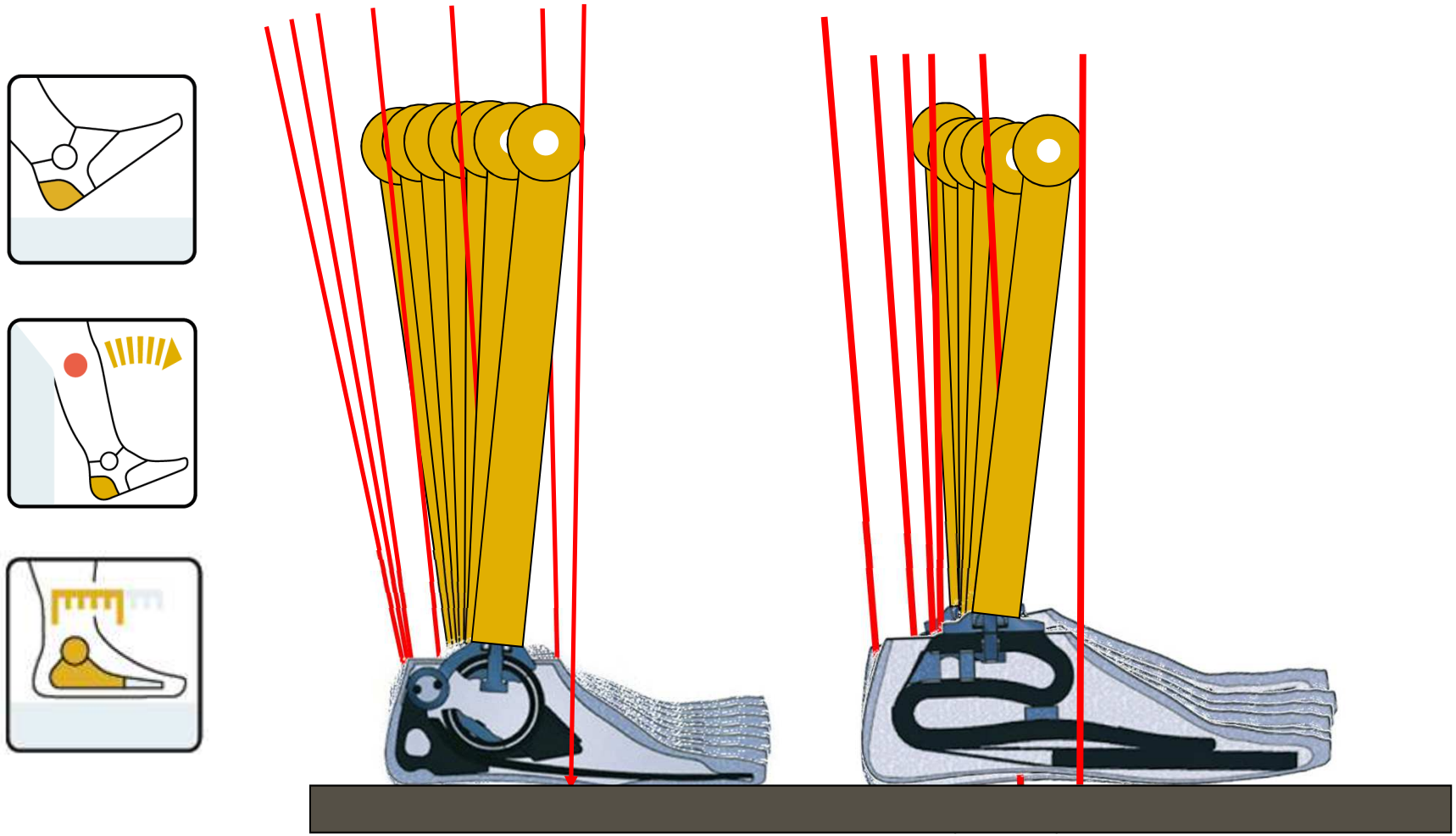
Biomechanical influence of prosthetic feet

Stability of COP with the Triton

- The load line normally falls close to the middle of the foot.
- The Triton has its most important rotation point where heel and connection spring are in contact (→ continuous force distribution)
- The load line stays around this point during vertical loading and unloading
- The foot feels stable and balanced especially for standing all the time

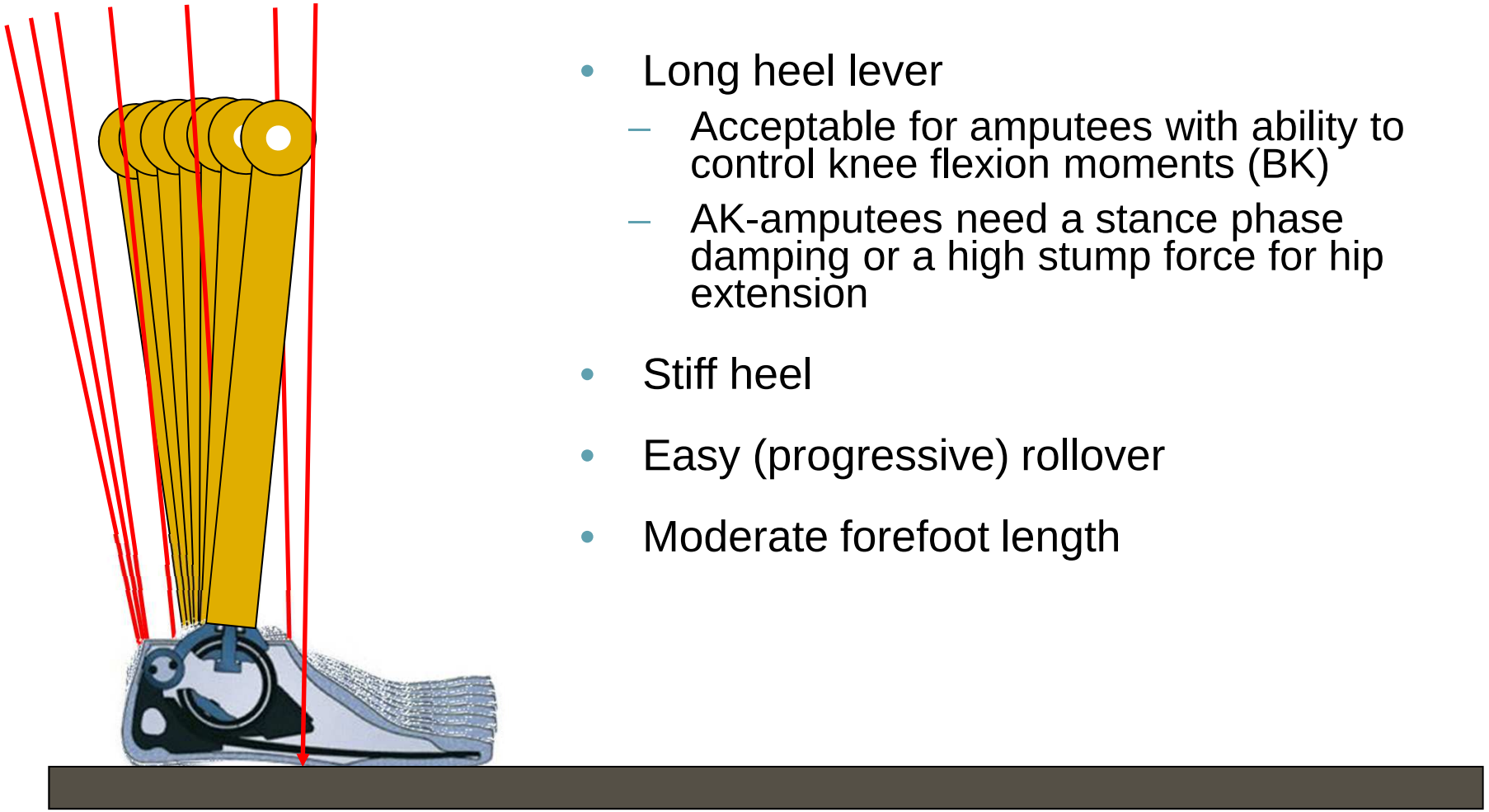
Biomechanical influence of prosthetic feet

Rollover characteristics of different prosthetic feet



Biomechanical influence of prosthetic feet

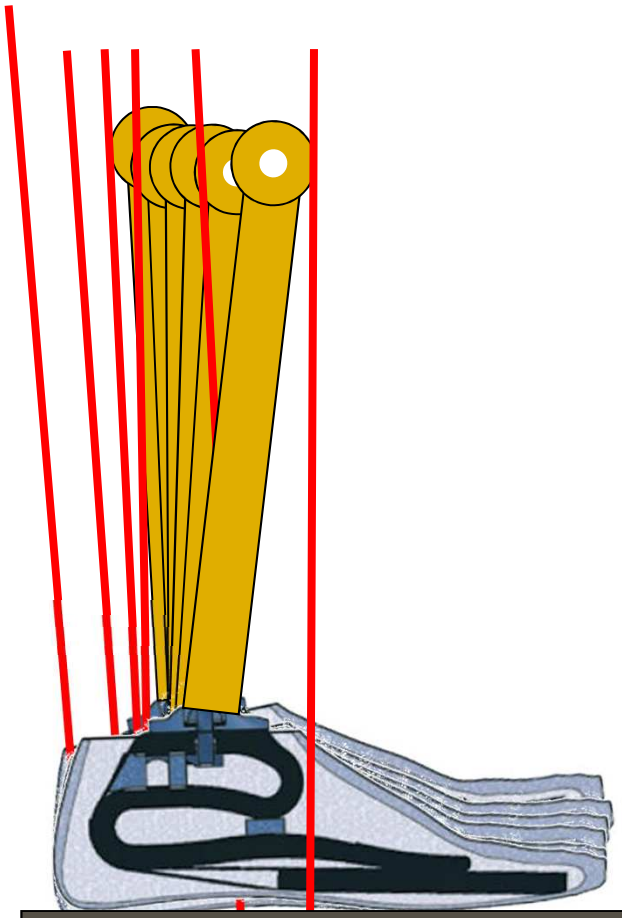
Characteristics 1C40 C-Walk



- Long heel lever
  - Acceptable for amputees with ability to control knee flexion moments (BK)
  - AK-amputees need a stance phase damping or a high stump force for hip extension
- Stiff heel
- Easy (progressive) rollover
- Moderate forefoot length

Biomechanical influence of prosthetic feet

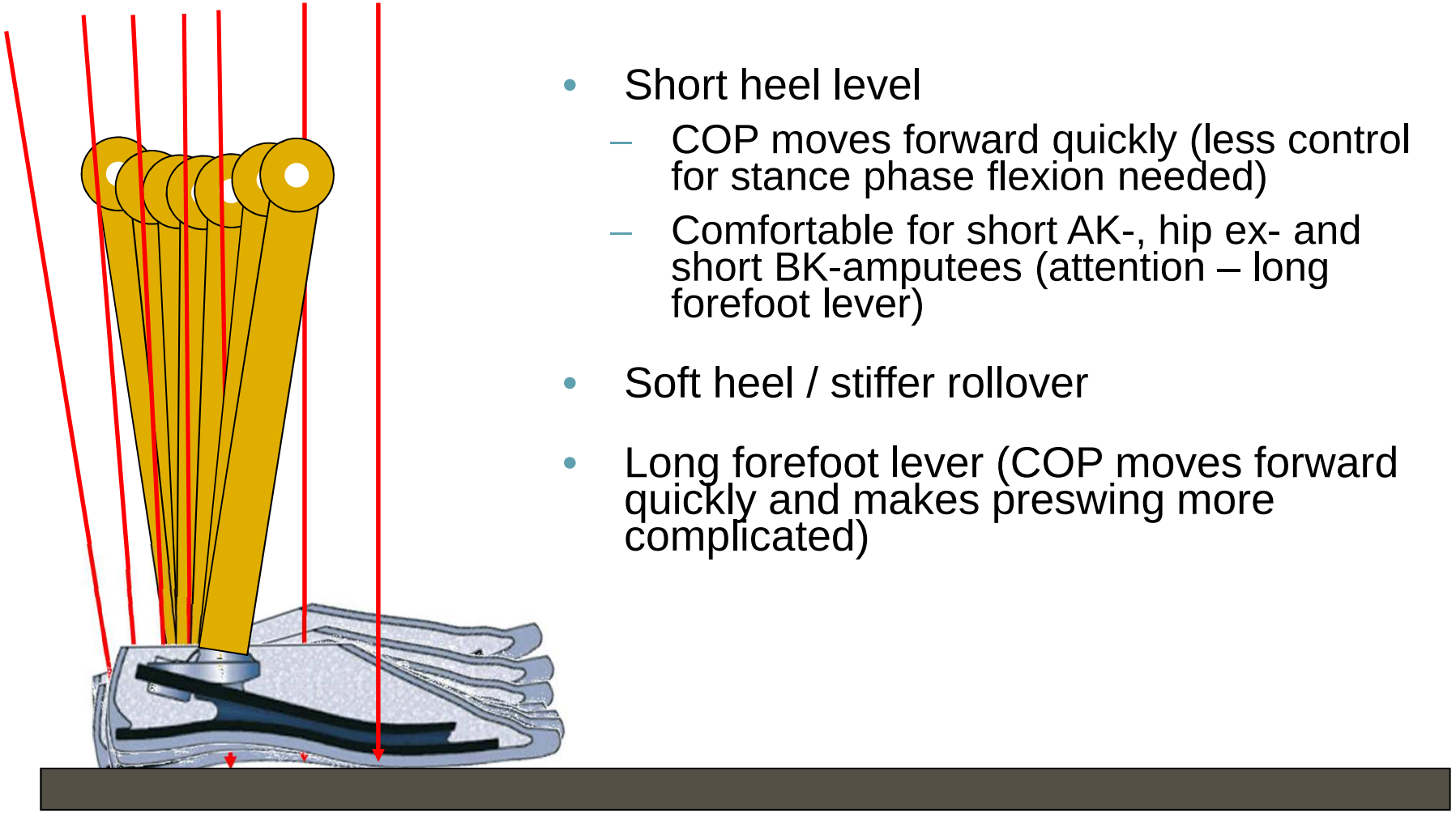
Characteristics 1D35 Dynamic Motion



- Heel lever becomes shorter a little bit faster than with 1C40 (preferred from AKs with short and intermediate limb length)
- Slightly softer heel than 1C40
- Slightly stiffer (linear) rollover than 1C40
- Behavior of the forefoot:
  - The forefoot is more stable and therefore better accepted by AKs
  - The forefoot lever is slightly shorter than with 1C40

Biomechanical influence of prosthetic feet

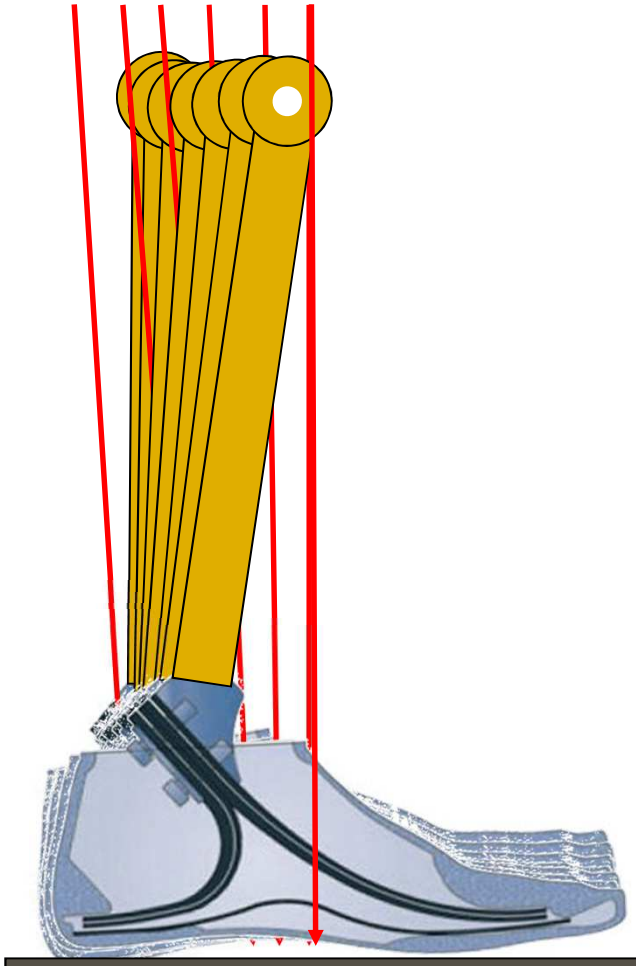
Characteristics 1E56 Axtion



- Short heel level
  - COP moves forward quickly (less control for stance phase flexion needed)
  - Comfortable for short AK-, hip ex- and short BK-amputees (attention – long forefoot lever)
- Soft heel / stiffer rollover
- Long forefoot lever (COP moves forward quickly and makes preswing more complicated)

Biomechanical influence of prosthetic feet

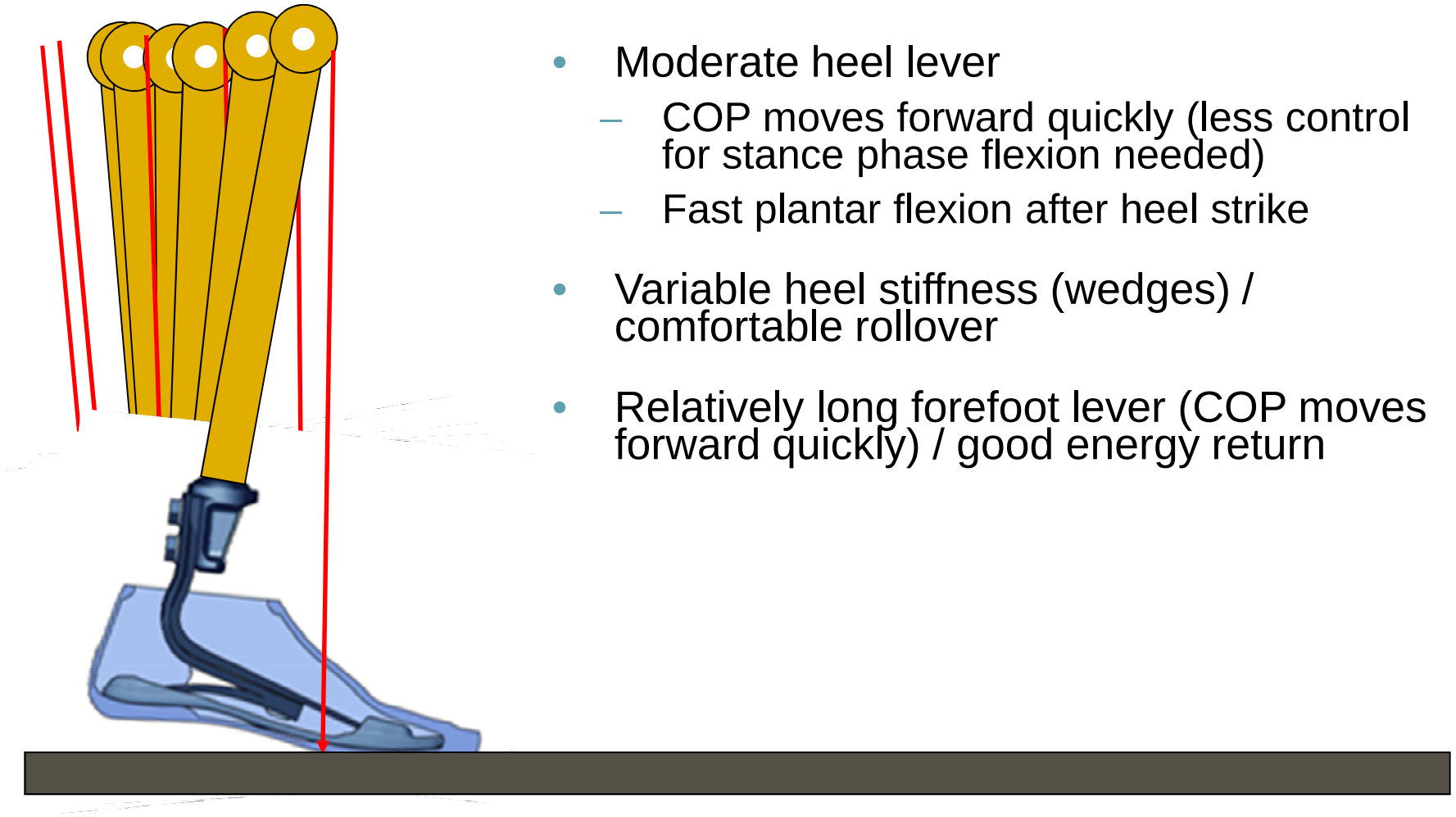
Characteristics 1C30 Trias



- Short heel lever
  - Good shock absorption
  - Low knee flexion moments
  - Smooth transition between heel and midfoot
- Soft heel / easy rollover
- Soft forefoot
  - Slow movement of the COP because of the flexible forefoot
  - Easy initiation of swing phase

Biomechanical influence of prosthetic feet

Characteristics 1C60 Triton



- Moderate heel lever
  - COP moves forward quickly (less control for stance phase flexion needed)
  - Fast plantar flexion after heel strike
- Variable heel stiffness (wedges) / comfortable rollover
- Relatively long forefoot lever (COP moves forward quickly) / good energy return

Biomechanical influence of prosthetic feet

Important tips for a Genium fitting

Out of experience no feet with too strong knee flexion properties should be used!

- Often described as too aggressive
- Hip extension power necessary to control forward momentum
- → use 1C60, 1D35, 1E56 for optimal behavior

Background? → **OPG (4° PreFlex)**

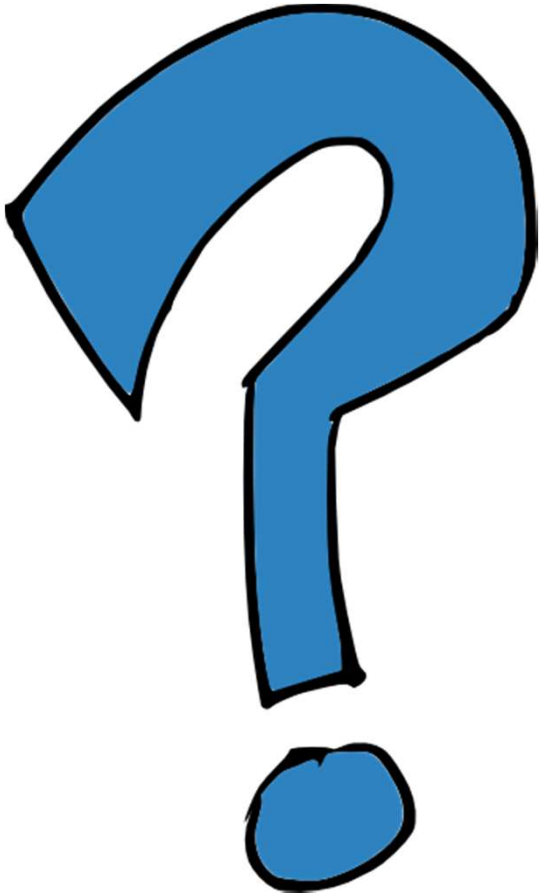
Biomechanical influence of prosthetic feet

Summary

These information is important to…

- understand the role of the foot in alignment
- choose the right foot for the amputee
- distinguish the feet, depending on the MG
- influence a poor performance of the prosthesis with the right foot

Let’s try out different feet…



Discover what moves us!

Referent

Kontaktdetails

www.ottobock.com

V 1.1 Created by: **Christian Reitinger** at **17.03.2014** On the basis by: **Sven Zarling**
approved by Int. Educ.: **xxx** at **yyy** approved by R&D: **xxx** at **yyy** approved by PM: **xxx** at **yyy**
last changed by: **Christian Reitinger** at **02.06.2014**
comments: Überarbeitet nach erster Trainerschulung

Glossar

Anterior:	to the front
Posterior:	to the back
Medial:	to the middle
Lateral:	to the side
Distal:	farthest away
Proximal:	closest to
Ventral:	pertaining to the front of any structure
Dorsal:	pertaining to the back of any structure
Plantar:	pertaining to the sole of the foot
COP:	Centre of Pressure (at foot)
GRF:	Ground Reaction Force

Biomechanical influence of prosthetic feet

Genium vs. the right (or left) foot

Heel:

heellever (vs. heellever shortening)
heel stiffness
+ _____
stance phase flexion support

COP TRANSFER (in relation to heel stiffness)

Anterior movement/COM:	Longer local hold-up
1E56 (H → MS) (heellever decreases fast)	1C40 (HC & MS) (heellever does not decrease fast) (katapult behaviour/fast walking)

STANCE PHASE FLEXION WALKING (link preflex)

Strong: (very agressive)	Moderate:	Weak:
1C40 1E57	1C60 1D35	1C30 1E56

Increasing stance phase flexion support:
1C60 & 1E56: heel stiffness can be adjusted by heel wedges
1E56: Socket flexion &DF (=posterior shift) ↑heellever, ↓forefootlever

Midfoot:

CURVE OF RESISTANCE

Linear:	Moderate:	Progresive:
1E57(very stiff) 1E56(stiff=stable) 1C30(very flexible)	1D35(←) 1C60(→)	1C40(unstable)

COP TRANSFER (MS → TO)

Anterior movement/COM:	Moderate:
1C30 (H→TO) → slow walking	1D35 1C60 1E56

Local hold-up:
1C40 (MS →TO)
(↑ R in C-spring, katapult behaviour/ → fast walking)

ROM (link ramps)

High:	Low (contraindication for ramps):
1C40 1C61	1E57 1E56

Forefoot:

STANCE PHASE EXTENSION SUPPORT (FF-lever)

Yes:	Moderate:	No:
1E56	1C60 1D35 1C40	1C30

ENERGY STORING (link FF-lever)

Yes:	Moderate:	No:
1C40(unstable) 1C60(stable) 1C30(flexible)	1D35 1C63	1E56(FF-Lever)

Advantage energy storing = energy return:
- short stumps, weak hip muscles, faster gait speed, easier swing initiation due to shorter FF-Lever

Disadvantage energystoring:
- shorter FF-lever = less adequate support.

Advantage longer FF-lever:
- stance phase extension support, adequete support allows to reach a higher stride length

Disadvantage longer FF-lever:
- harder swing initiation due to longer FF-lever

e.g. 1E56: Socket flexion +DF (=posterior shift) ↑ heellever, ↓forefootlever

Genium X3= 1C63/1C64