GAIT ANALYSIS - Normal Gait

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Contents

1. Gait basics
2. Gait analysis lab
3. Normal gait
4. Abnormal gait

Gait Basics

Definition of gait

Principle of gait

- CNS control
- Bones, joints, muscles/tendons
- Anatomical/biomechanical gait description limited to pelvis and lower limbs

Joints and Bones

- **Hip**: pelvis and femur
- **Knee**: femur, tibia/fibula and patella
- **Ankle**: tibia/fibula and talus

- Foot: >26 bones

See video for joint ROM

Muscles - Histology

- **Type 1 fibres**
  - Myoglobin++ (red)
  - Weak/slow contraction, but not fatigable
- **Type 2b fibres**
  - Glycolytic enzyms++ (white)
  - Strong/fast contraction, but fatigable
- **Type 2a fibres** (between 1 and 2b)

Muscle - Contraction

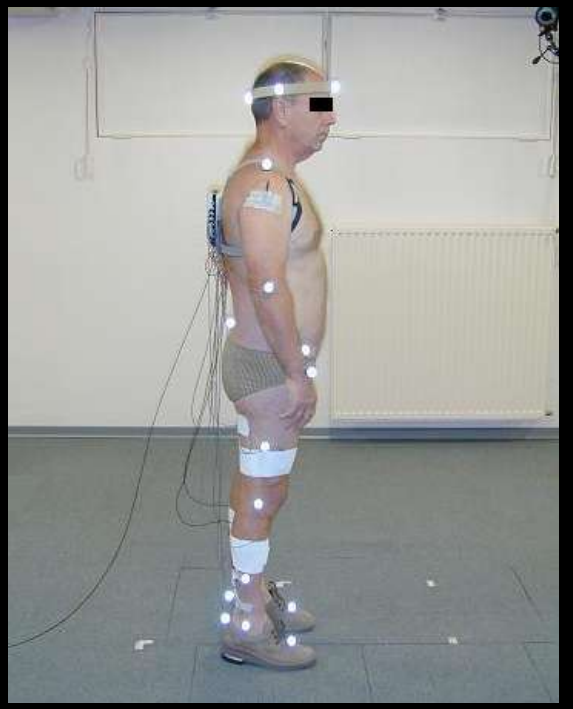
- Concentric contraction:
  - Shortening muscle length
  - Positive work
- Eccentric contraction:
  - Lengthening muscle length
  - Negative work

See video of Soleus muscle

Gait Analysis Laboratory

Types of analysis

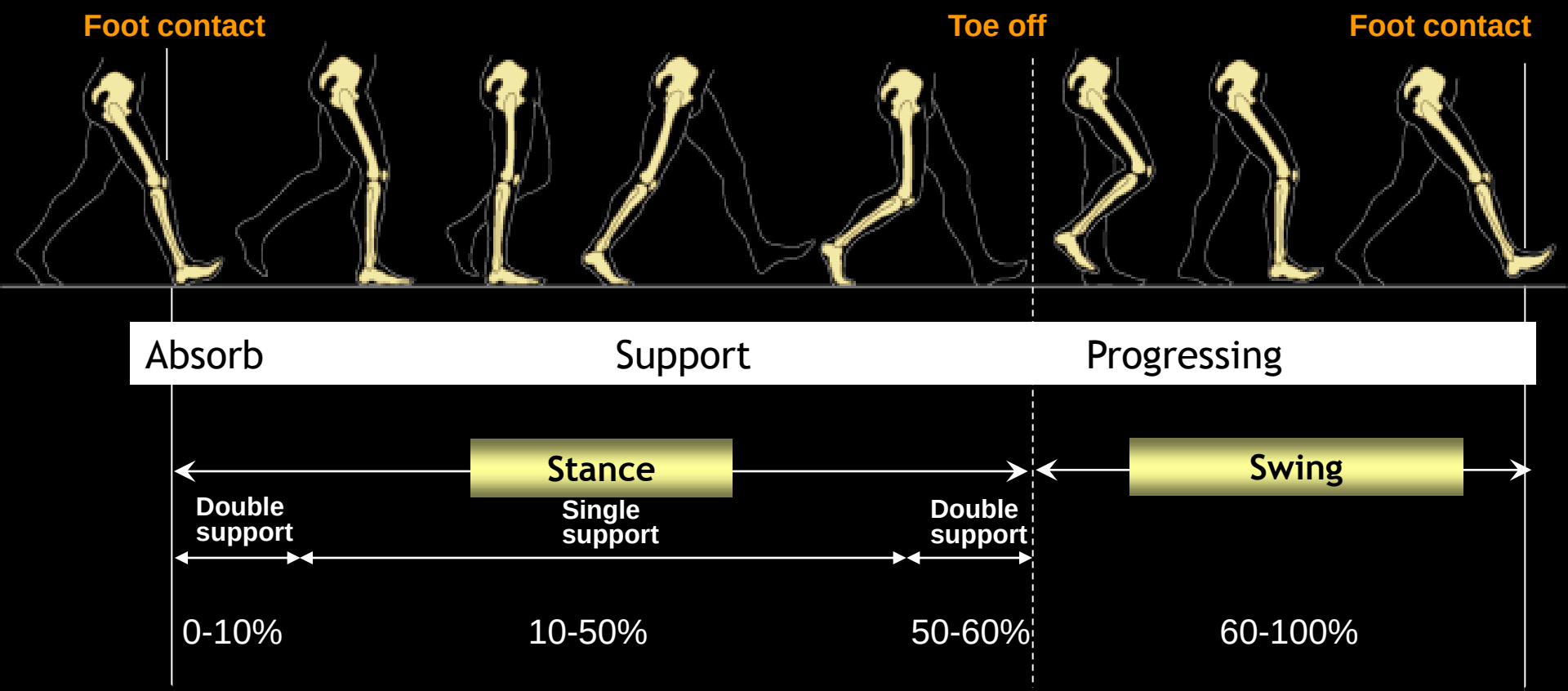
- Clinical observations
- Video
- Quantified analysis:
  - Vicon (IR camera)
  - Force platform
  - EMG
  - Pressure platforms
  - Energy consumption



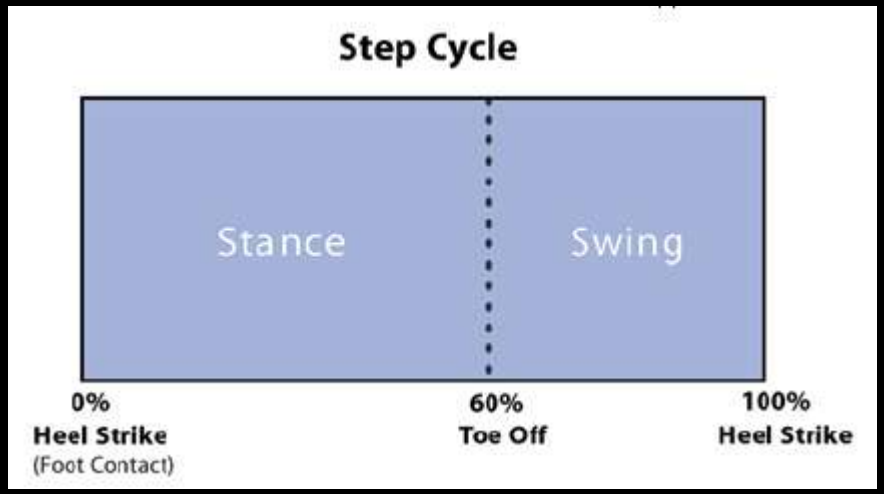
Gait definition

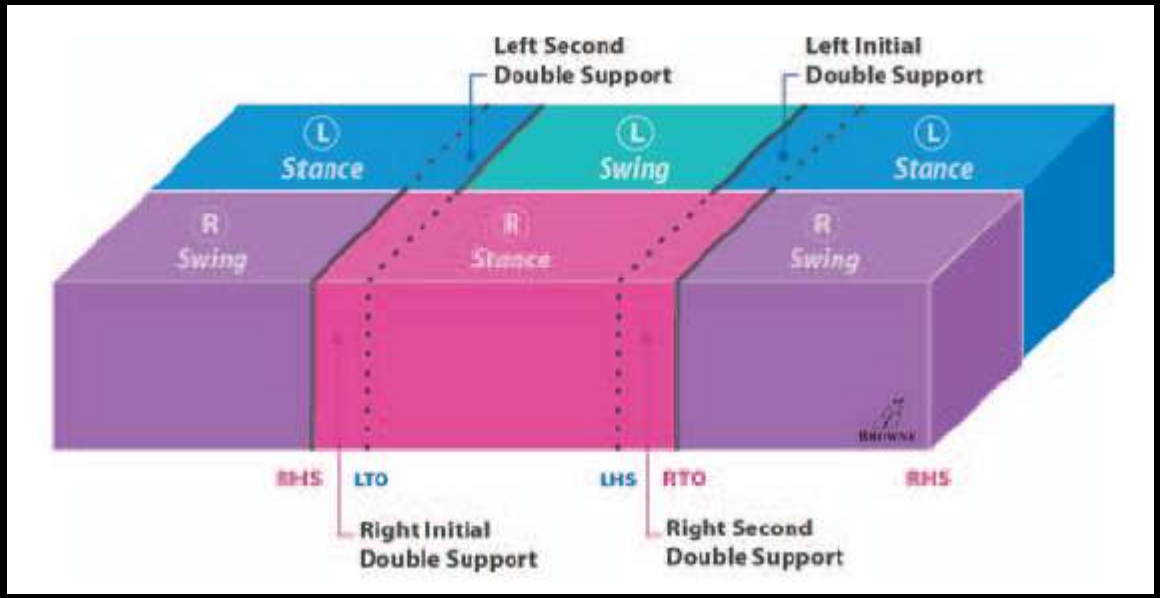
- Automatic function
- Cycle
  - Begins with foot contact
  - Standing phase and swinging phase
  - 2 periods of double standing

Gait Cycle


Foot contact
Toe off
Foot contact
Absorb
Support
Progressing
Stance
Swing
Double support
Single support
Double support
0-10%
10-50%
50-60%
60-100%

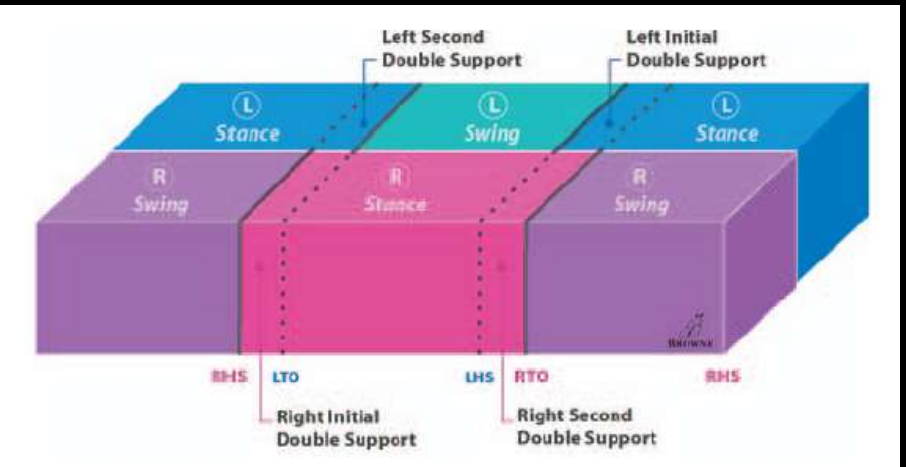
Gait Cycle

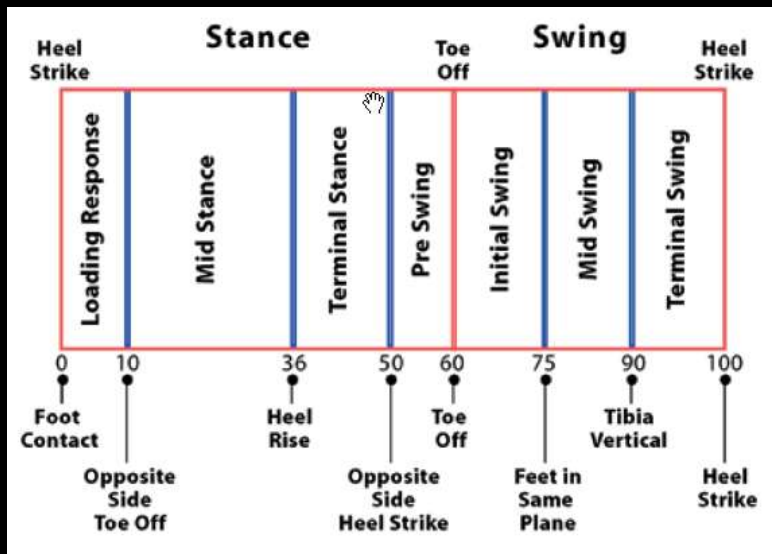

Step Cycle
Stance
Swing
0%
Heel Strike
(Foot Contact)
60%
Toe Off
100%
Heel Strike


Left Second
Double Support
Left Initial
Double Support
L
Stance
L
Swing
L
Stance
R
Swing
R
Stance
R
Swing
RHS
LTO
LHS
RTO
RHS
Right Initial
Double Support
Right Second
Double Support

1. Loading Response

- Initial contact: 0-3%
- Loading response: 3-10%
- Double support: load transfer
- Stabilise lower limb
- Absorb impact



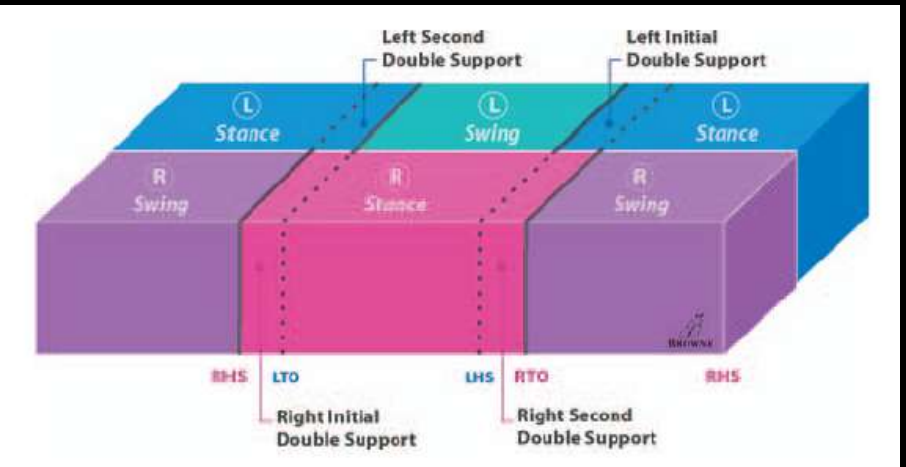


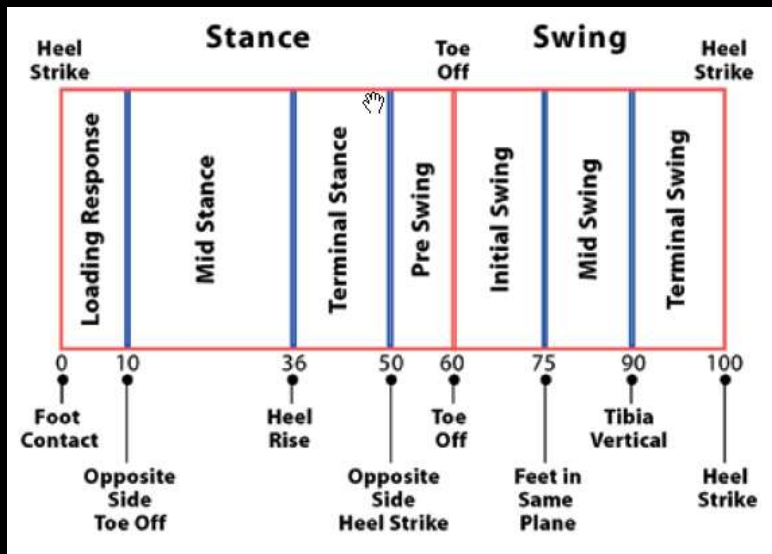
2. Mid Stance

Support load

Stability (controlateral swing)

- Foot flat on the ground



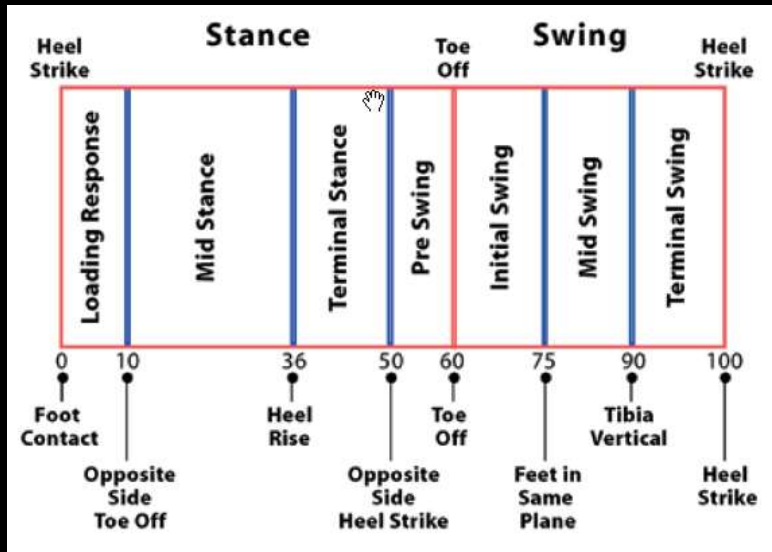


3. Terminal Stance

Support load

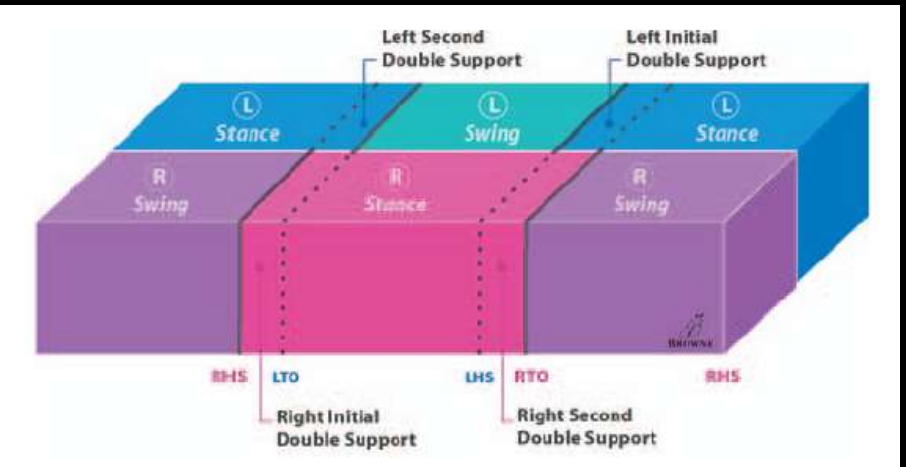
Stability (controlateral swing)

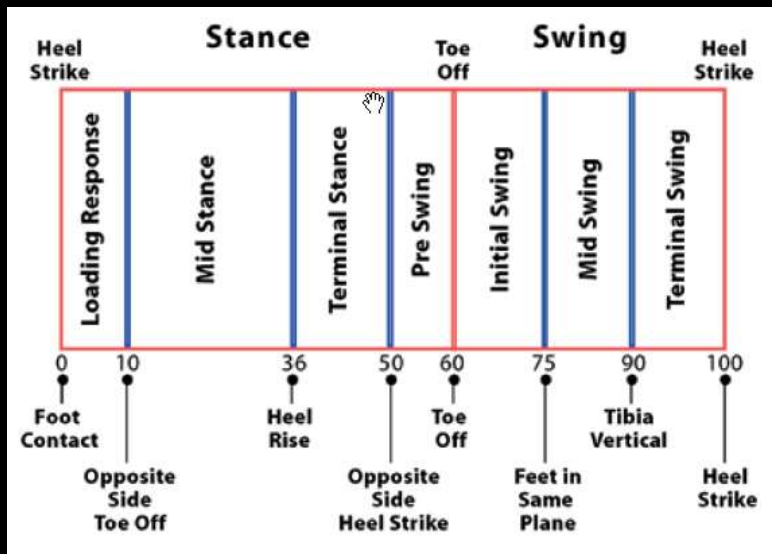
- Weight of body passes forward



4. Pre Swing

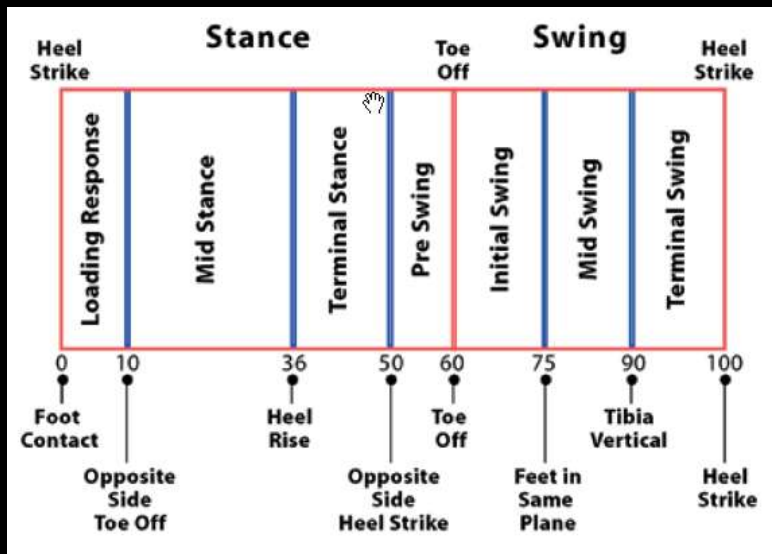
- Double support: load transfer
- Ready for swing





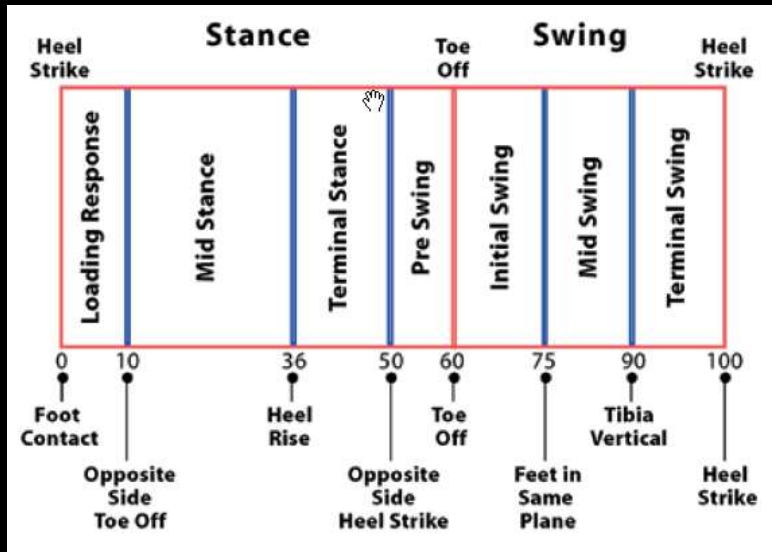
5. Initial Swing

- First third
- Foot clearance:
  - Knee flexion
  - Ankle dorsal flexion



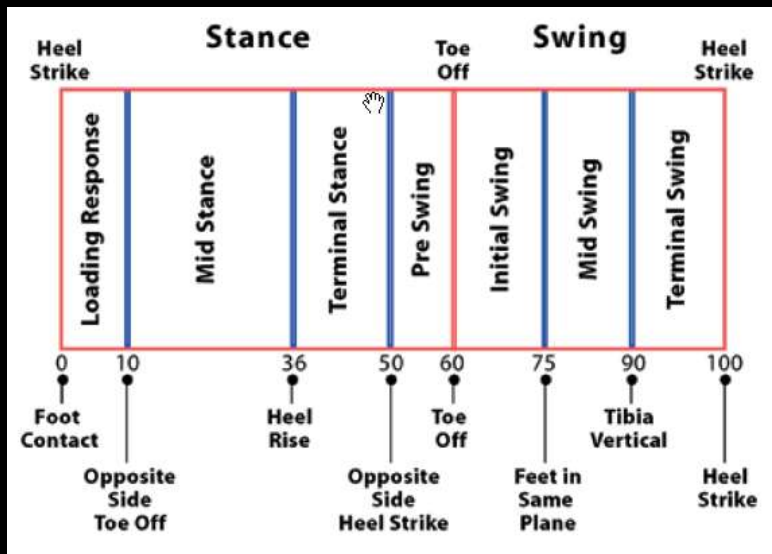
6. Mid Swing

- Second Third



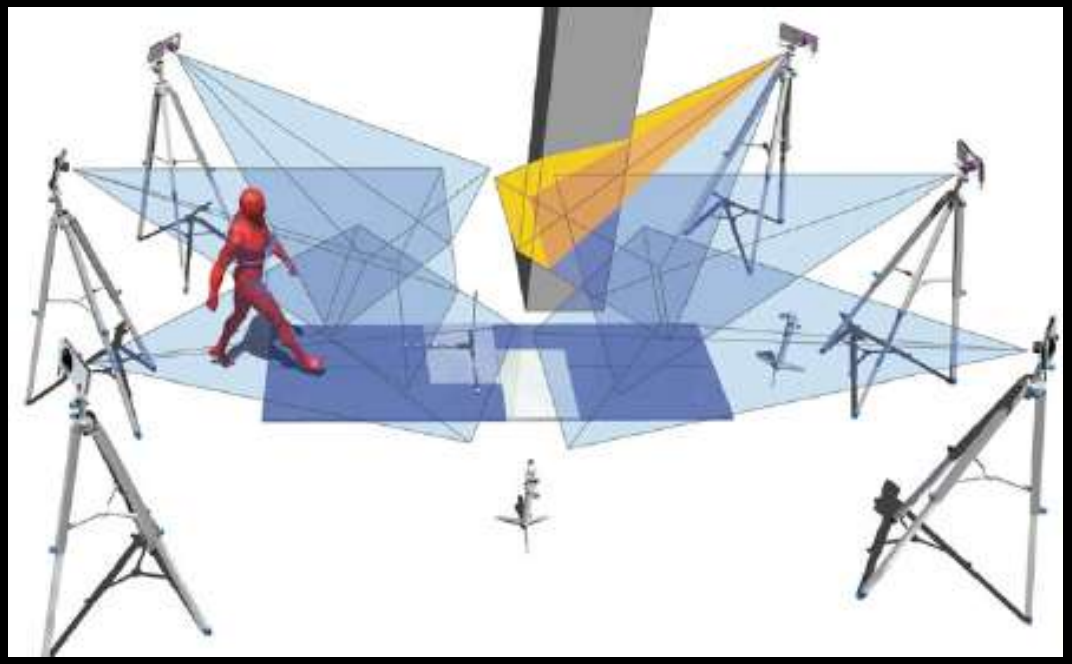
7. Terminal Swing

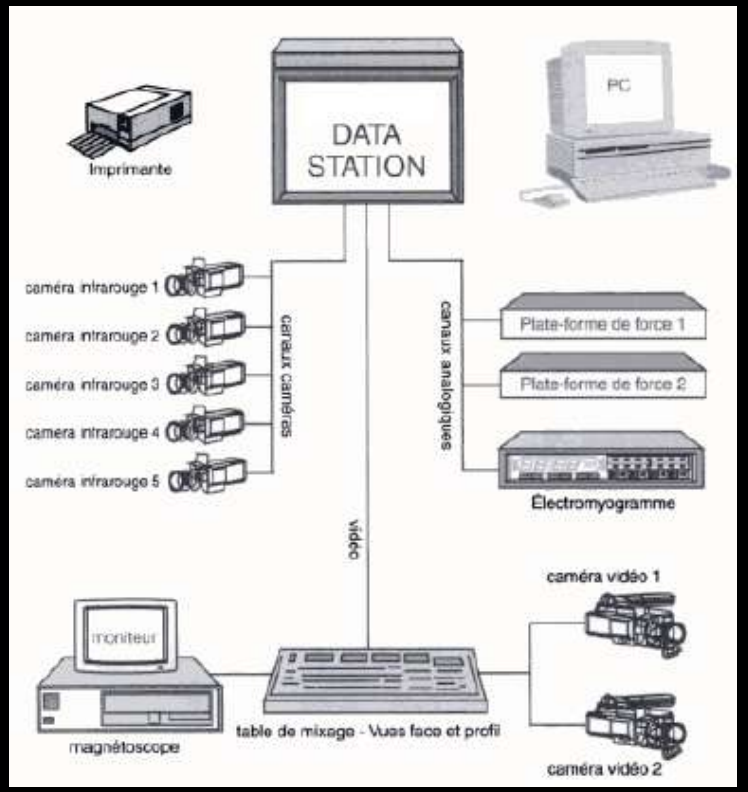
- Last third

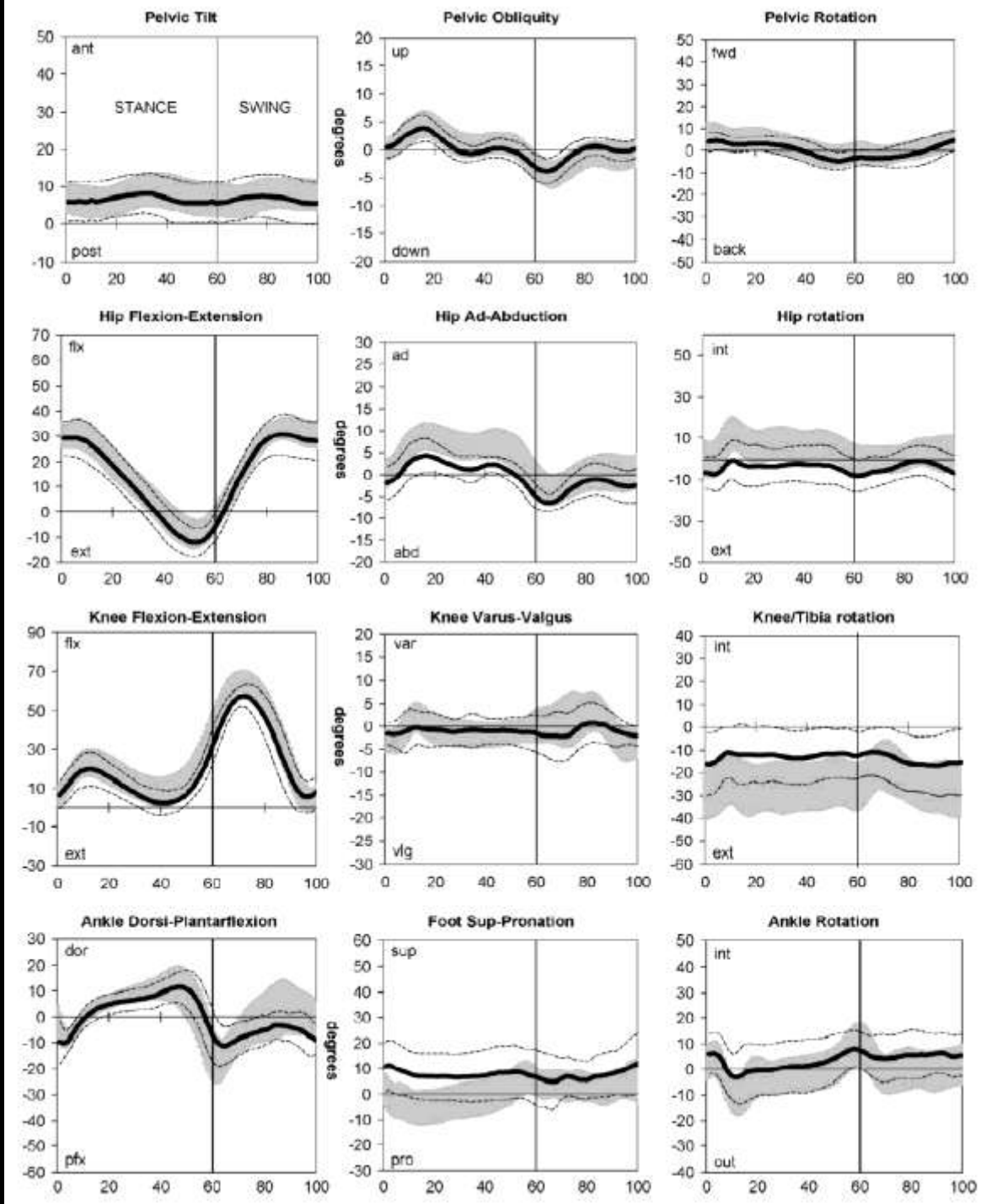


Gait Lab

Gait Lab




Imprimante
DATA STATION
PC
caméra infrarouge 1
caméra infrarouge 2
caméra infrarouge 3
caméra infrarouge 4
caméra infrarouge 5
câbles caméras
canaux analogiques
Plate-forme de force 1
Plate-forme de force 2
Électromyogramme
vidéo
caméra vidéo 1
moniteur
magnétoscope
table de mixage - Vues face et profil
caméra vidéo 2


Pelvic Tilt
ant
STANCE
SWING
post
Pelvic Obliquity
up
down
degrees
Pelvic Rotation
fwd
back
Hip Flexion-Extension
flx
ext
Hip Ad-Abduction
ad
abd
degrees
Hip rotation
int
ext
Knee Flexion-Extension
flx
ext
Knee Varus-Valgus
var
vlg
degrees
Knee/Tibia rotation
int
ext
Ankle Dorsi-Plantarflexion
dor
pfx
degrees
Foot Sup-Pronation
sup
pro
Ankle Rotation
int
out

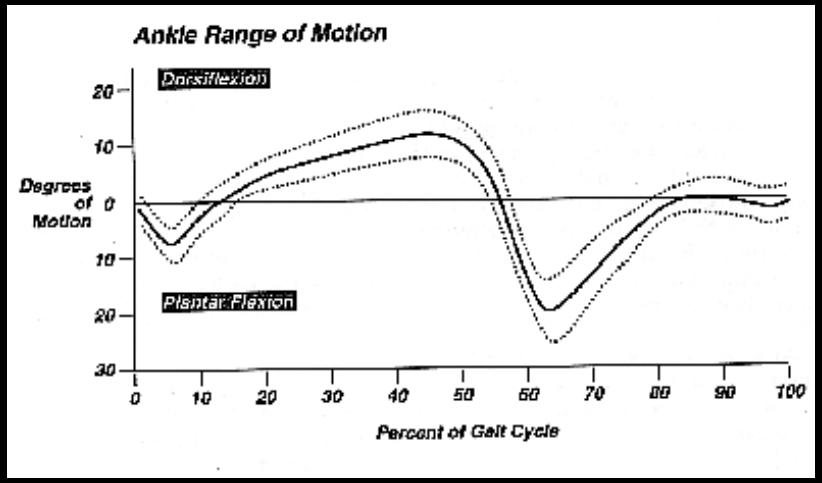
More definitions…

- Closed chain = weight bearing
- Open chain = NWB

Same muscle has different function!

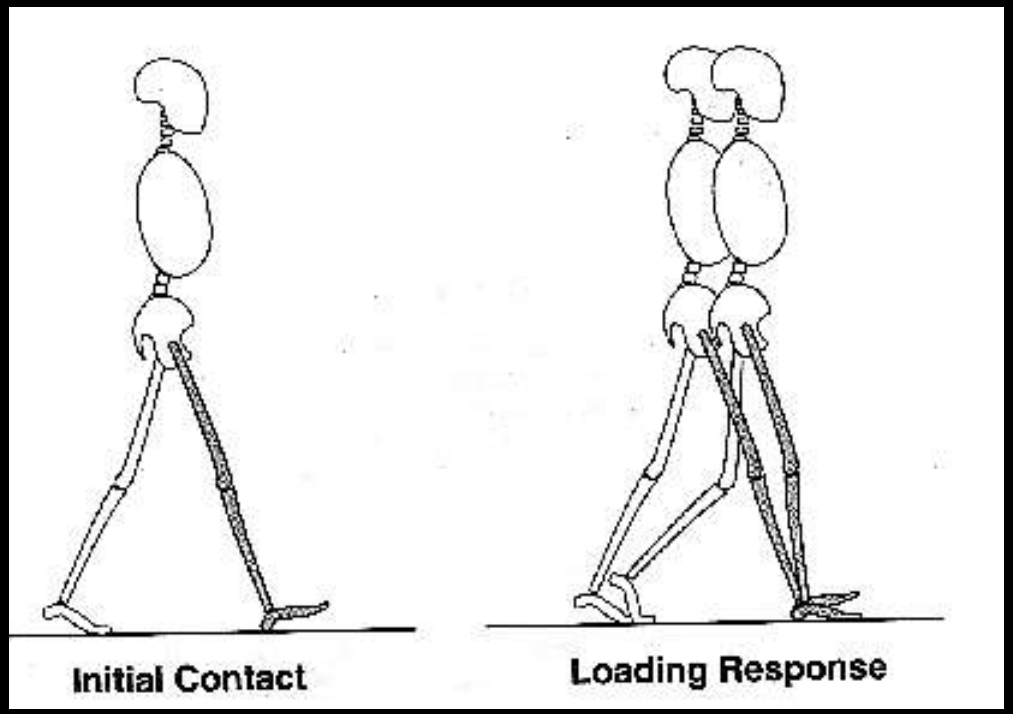
Ankle Movement

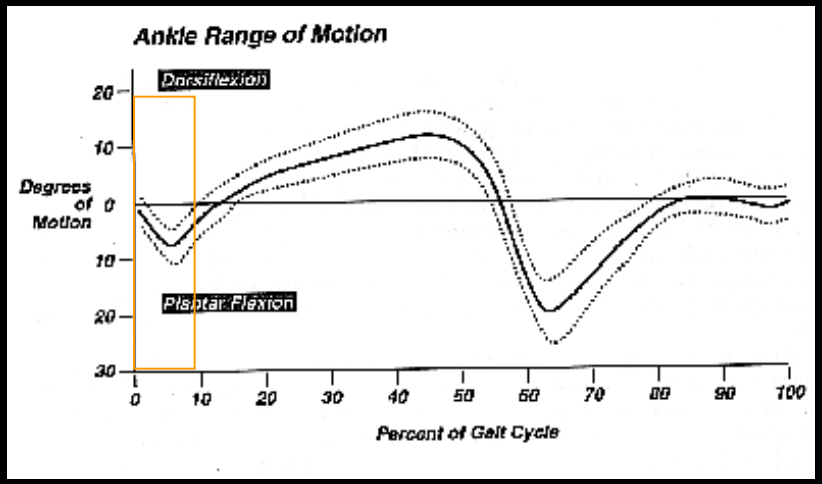
- Kinematic: angular motion around a joint
- Foot movement to the tibia
- 0° = neutral position
- Above = dorsal flexion
- Below = plantar flexion



Ankle Kinematic – Loading Response

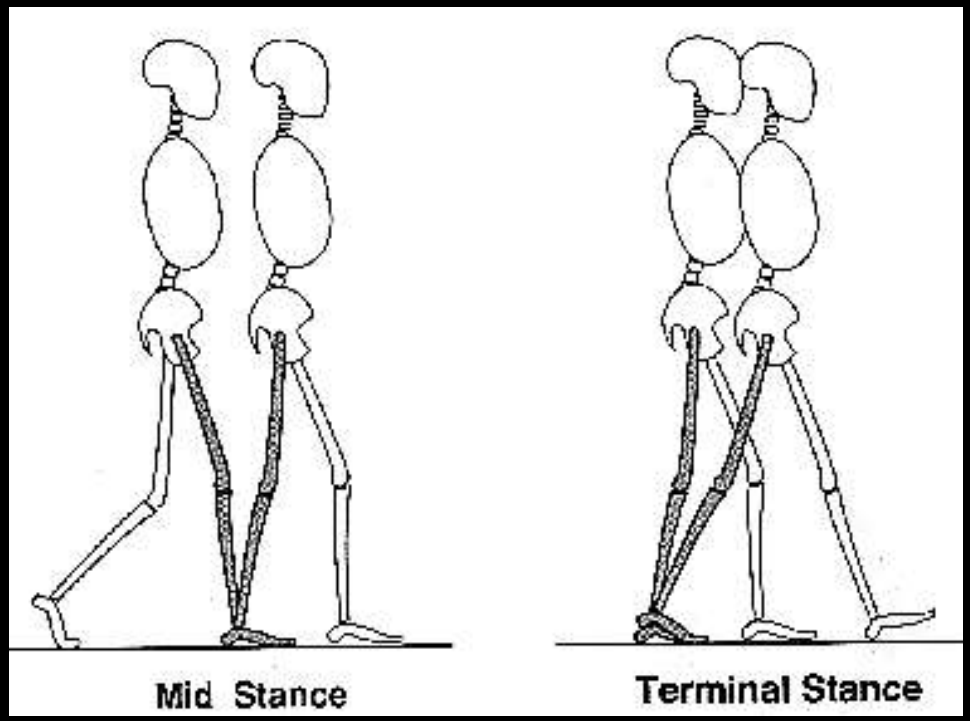
- Neutral position: 30° to the ground
- PF: foot flat on the ground
- First rocker

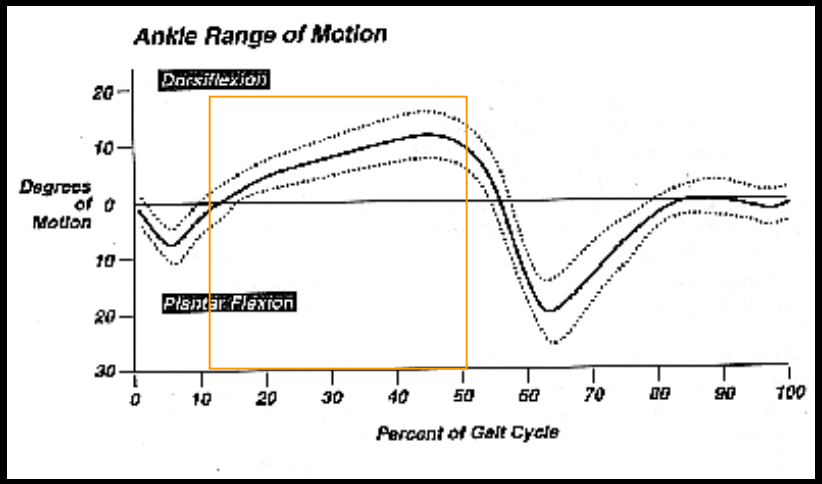




Ankle Kinematic – Stance

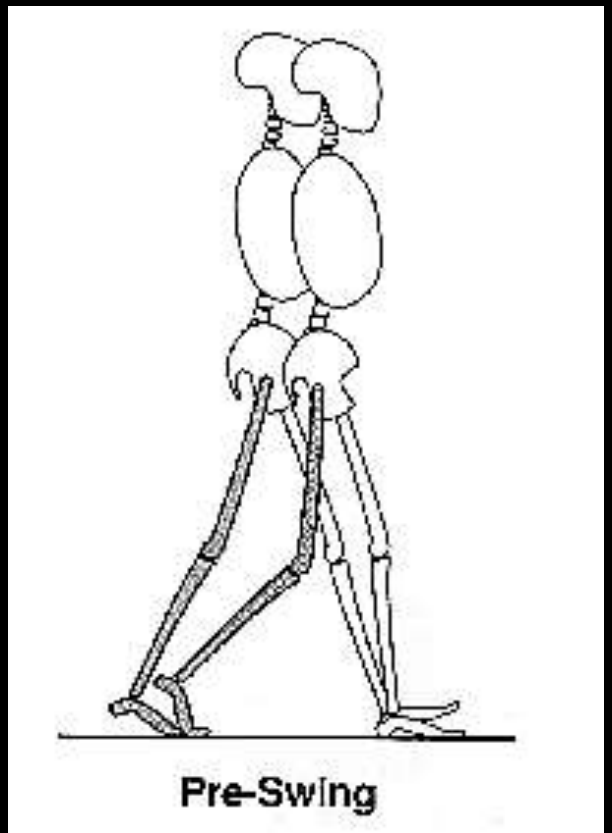
- DF: Tibia forward
- DF max = 15°
- Second rocker

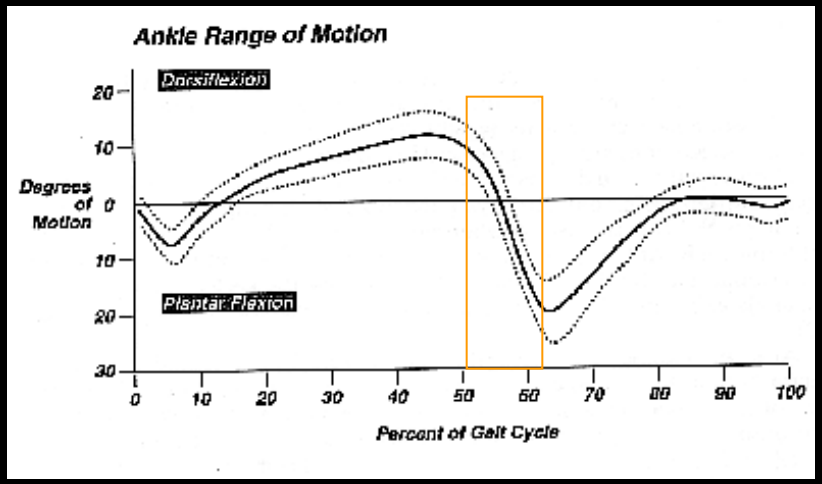




Ankle Kinematic – Pre Swing

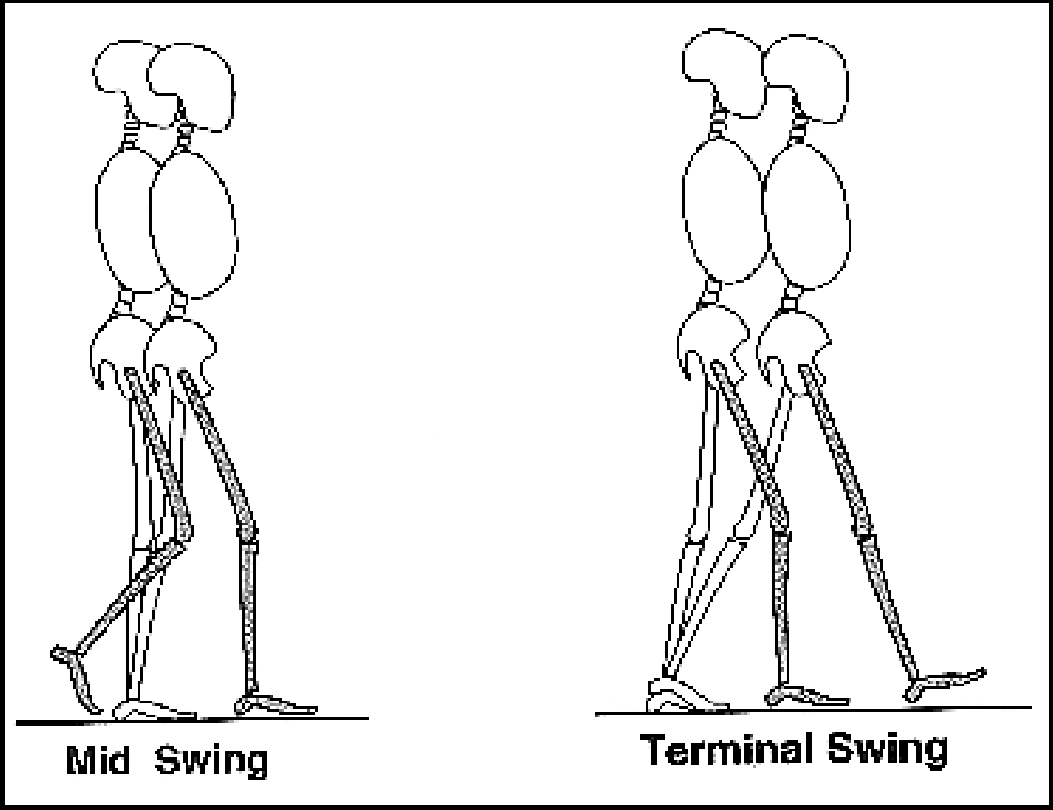
- Fast PF up to 20°
- Third rocker

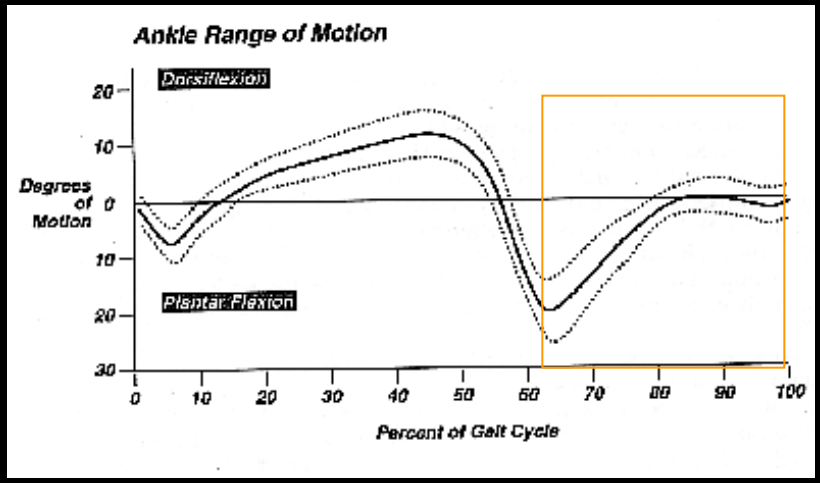




Ankle Kinematic – Swing

- Return to a neutral position



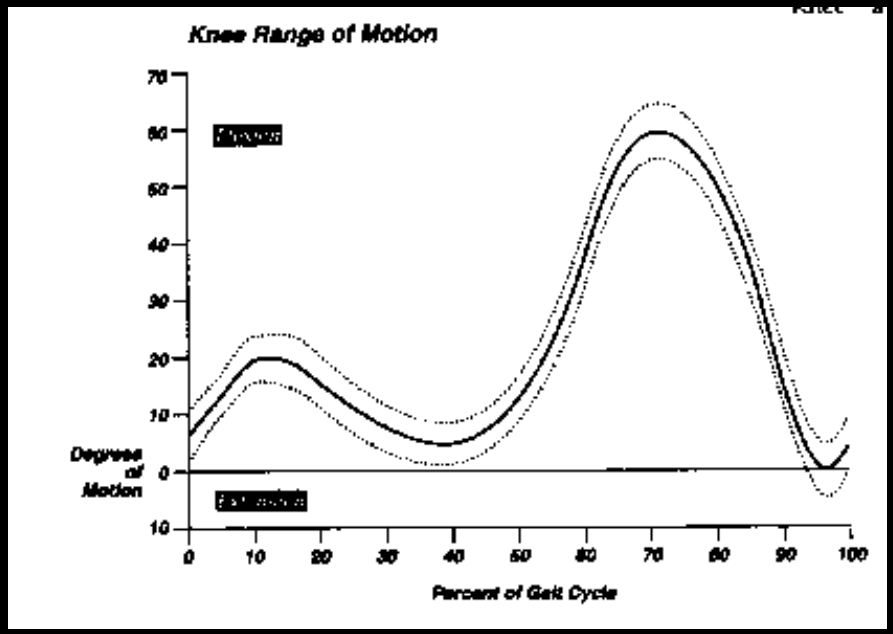


Ground Reaction Force (GRF)

- Newton’s third law
- 3D vector
- Static (body weight) and
  Dynamic (speed of ground contact)
- Orientation: passive angular motion
- Kinetics

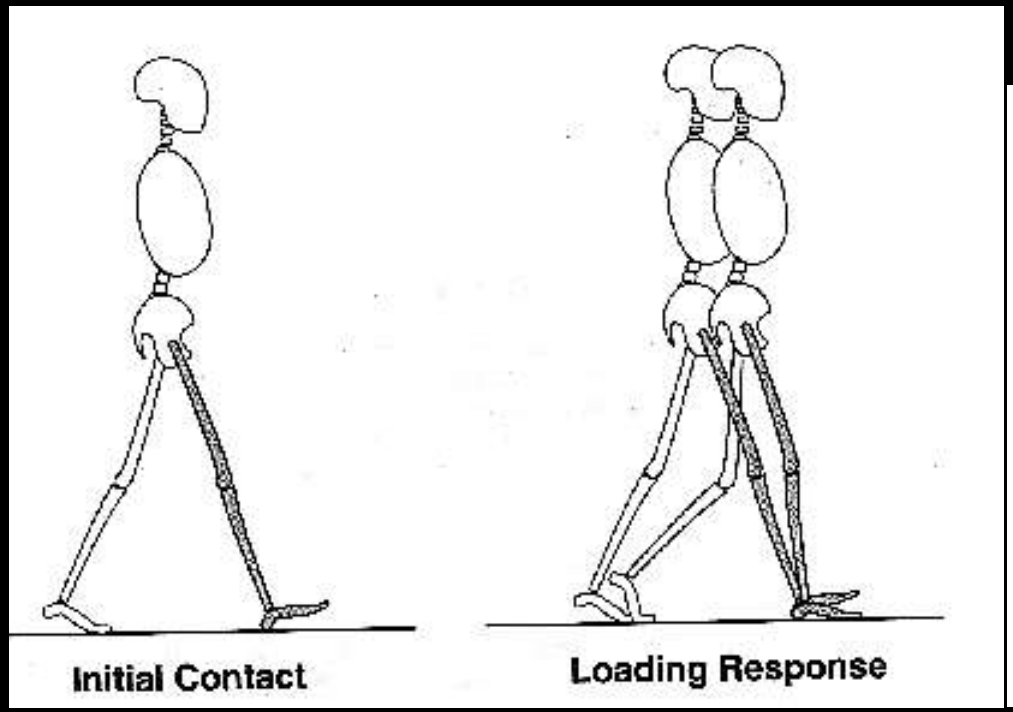
Knee Movement

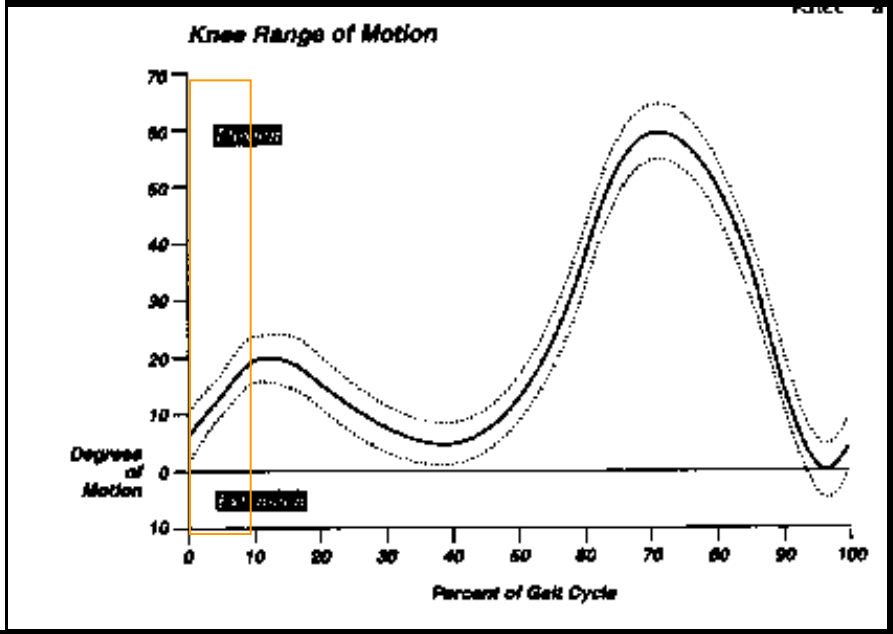
- Kinematic: angular motion around a joint
- Tibia movement to the femur
- 0° = neutral position
- Above = flexion
- Below = extension
- No extension!



Knee Kinematic – Load Response

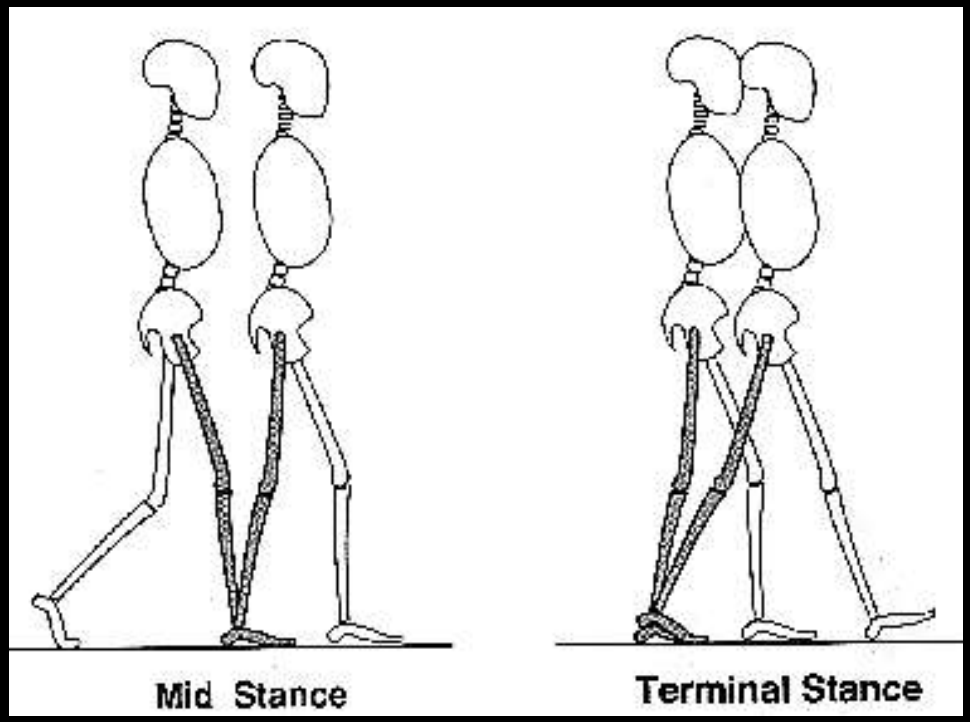
- Initial contact: 5°
- Flexion up to 20°

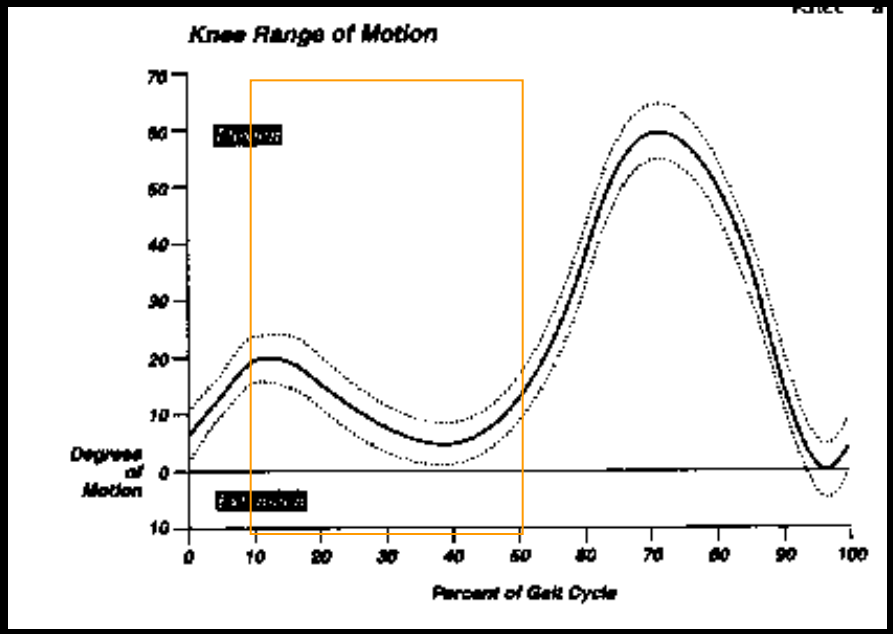




Knee Kinematic – Stance

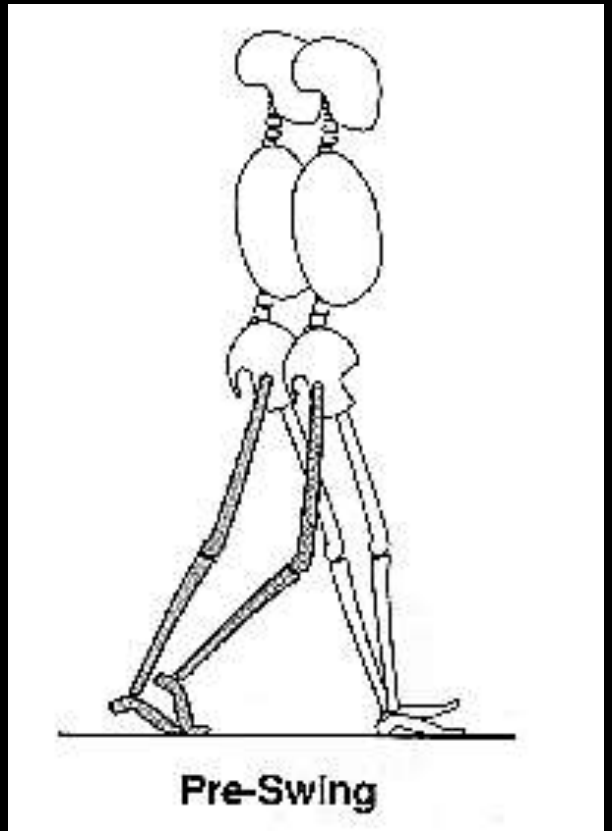
- Reduced flexion
- Max at 40%

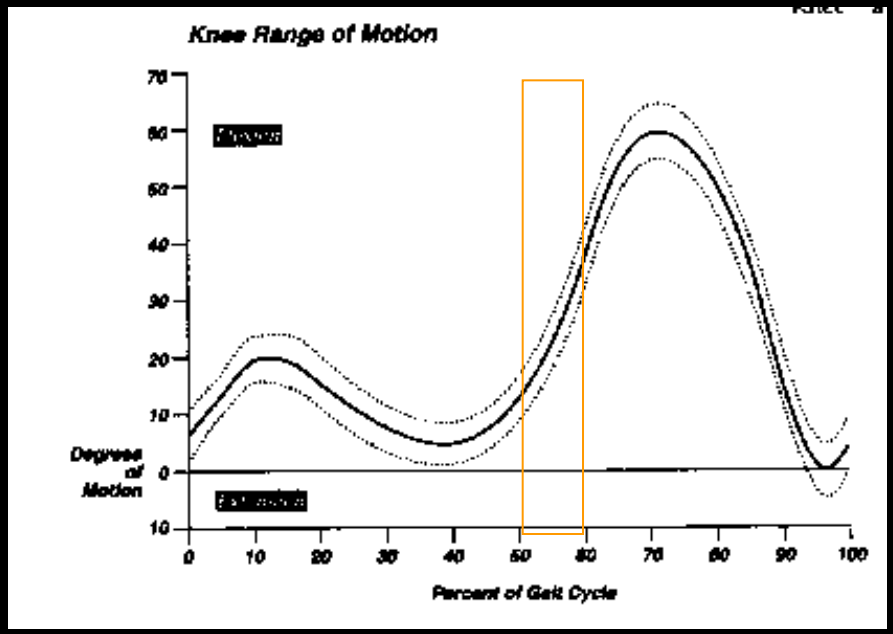




Knee Kinematic – Pre Swing

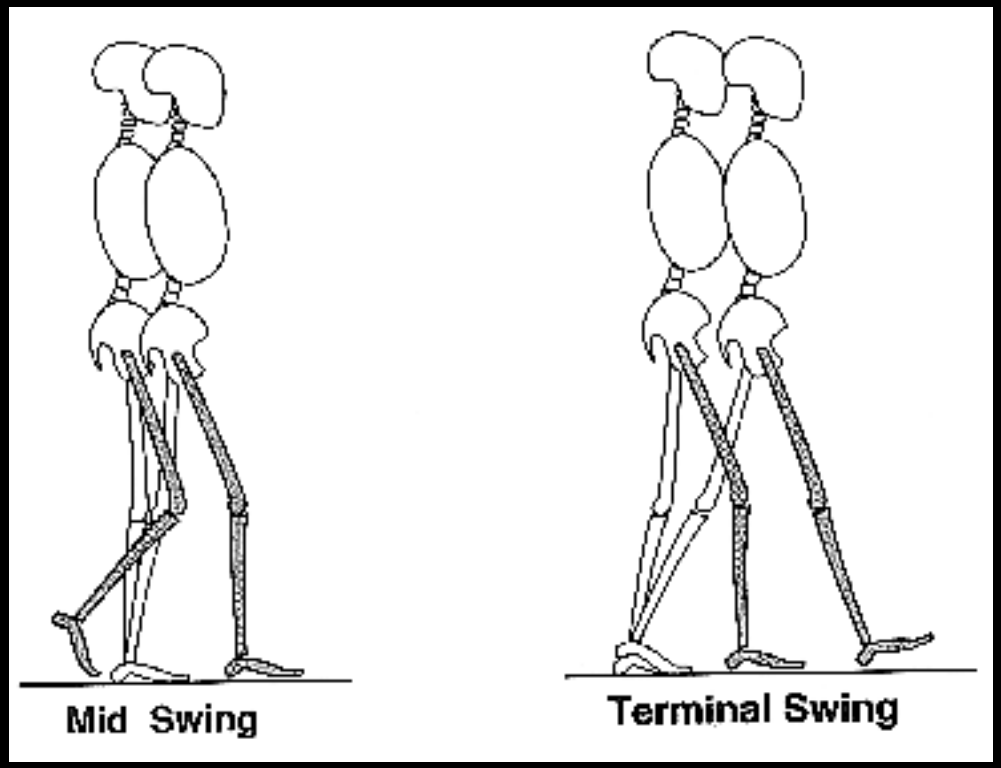
- Fast flexion

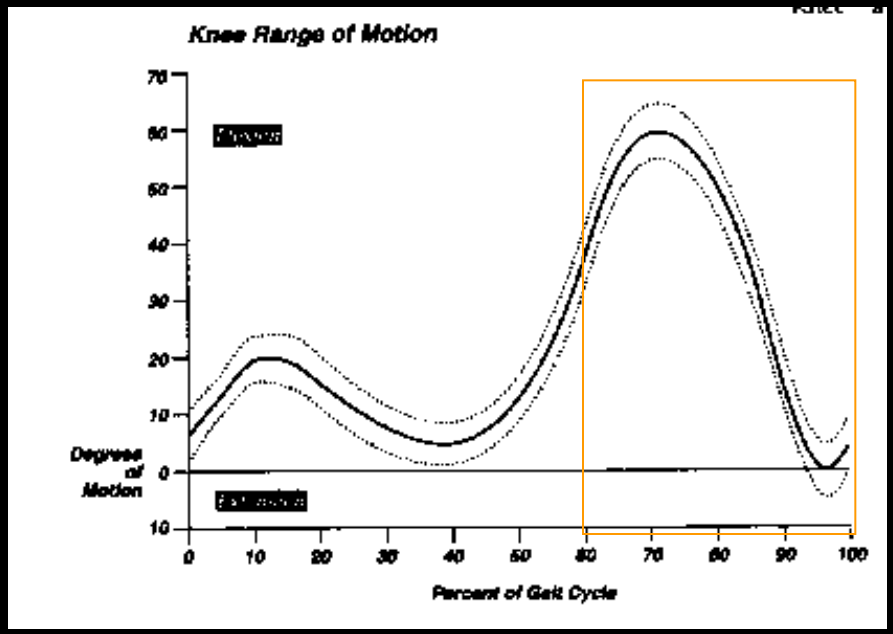




Knee Kinematic – Swing

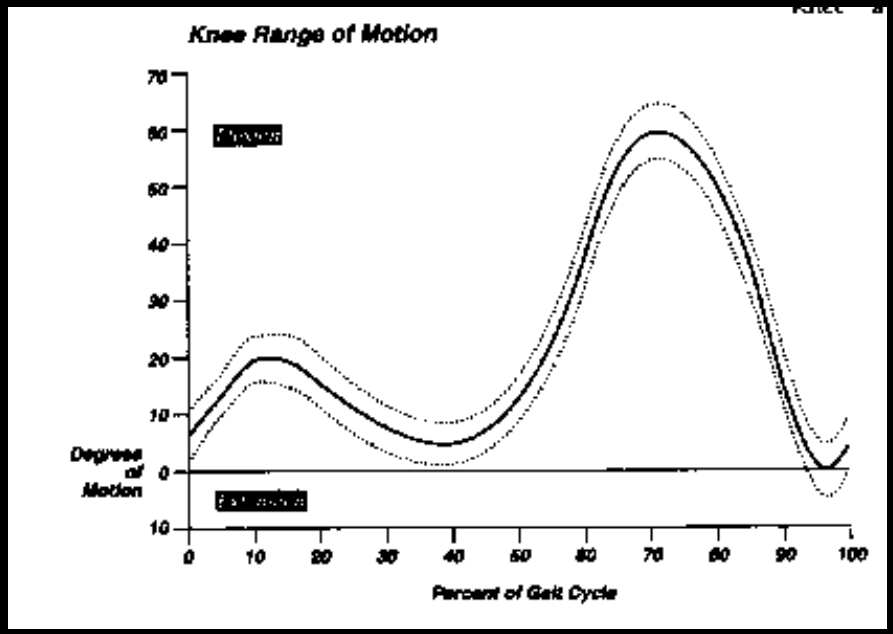
- Max flexion at the end of initial swing





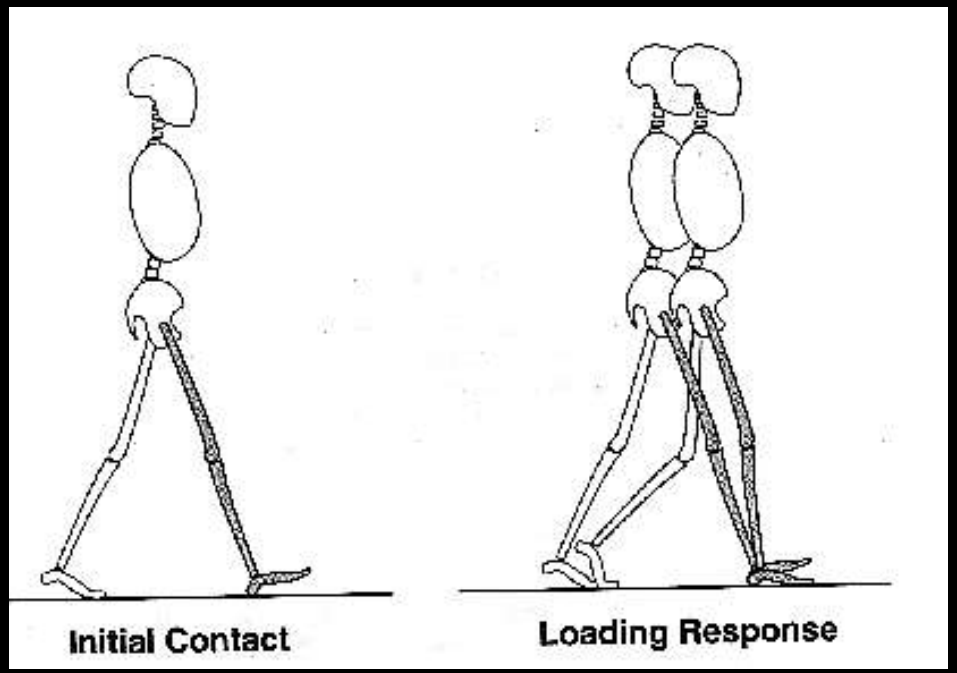
Hip Movement

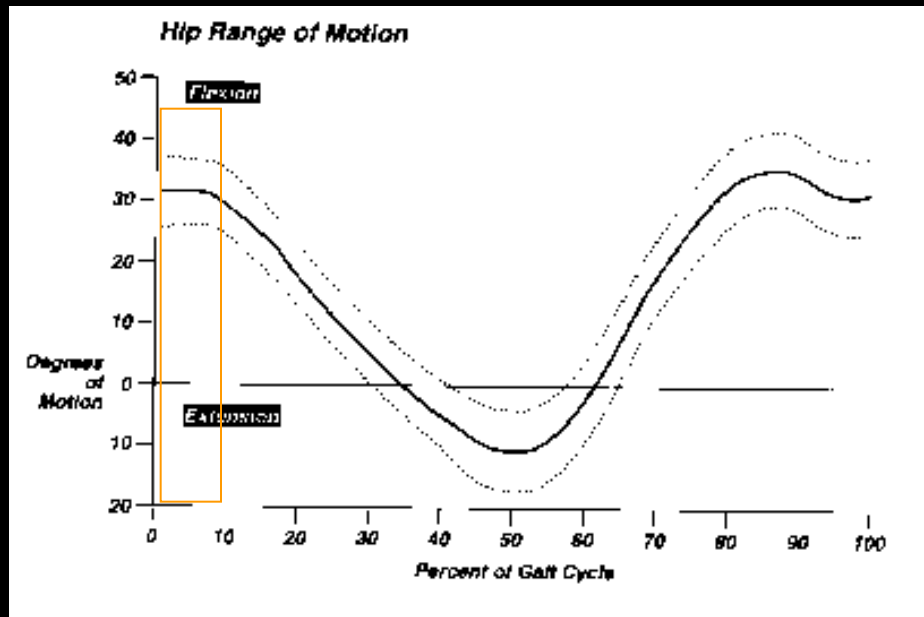
- Kinematic: angular motion around a joint
- femur movement to the pelvis
- 0° = neutral position
- Above = flexion
- Below = extension



Hip Kinematic – Load Response

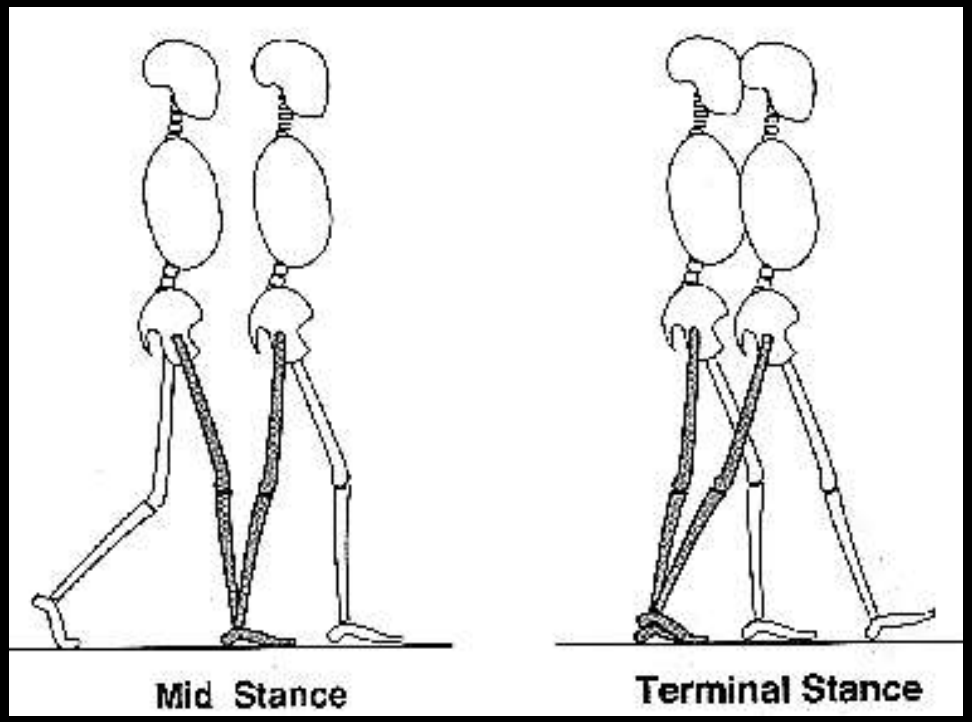
- Initial contact: 30° flexion

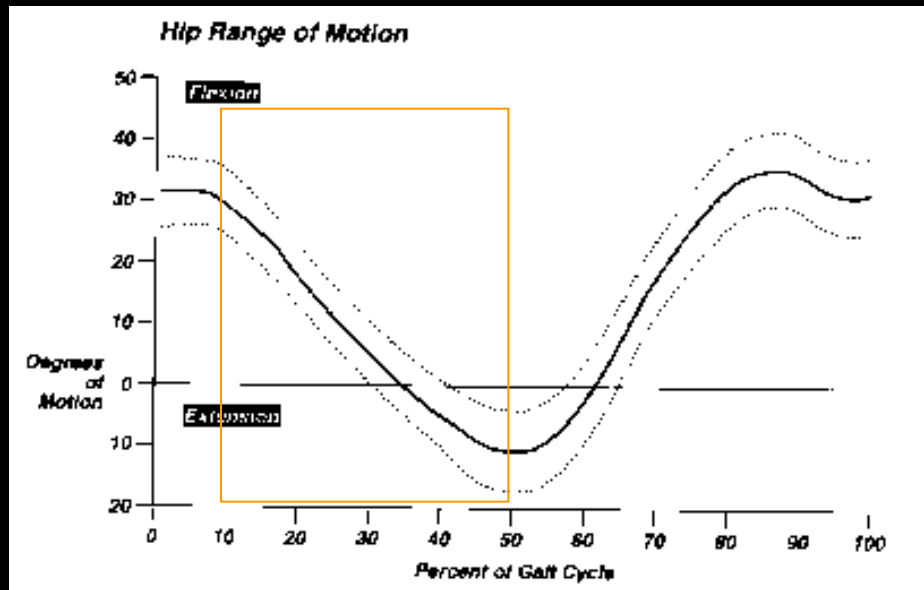




Hip Kinematic – Stance

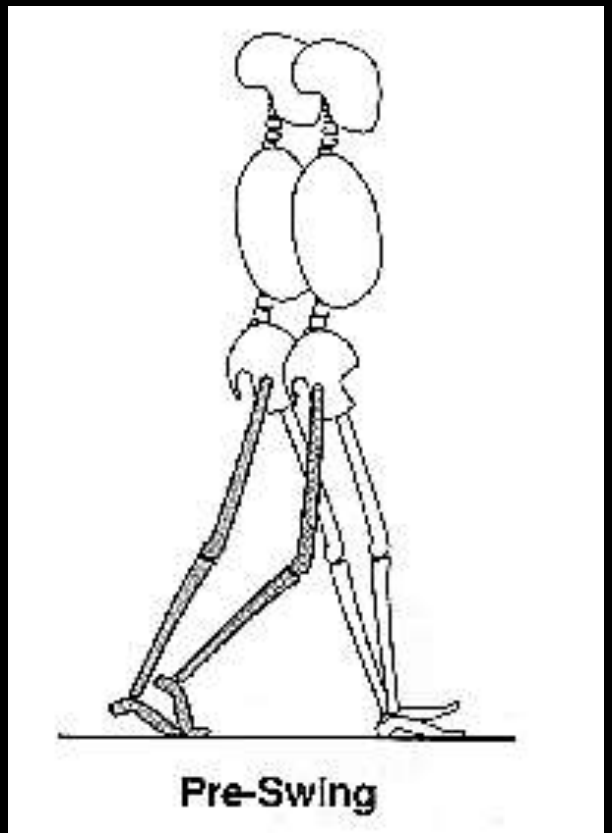
- Neutral
- Max extension at 50%

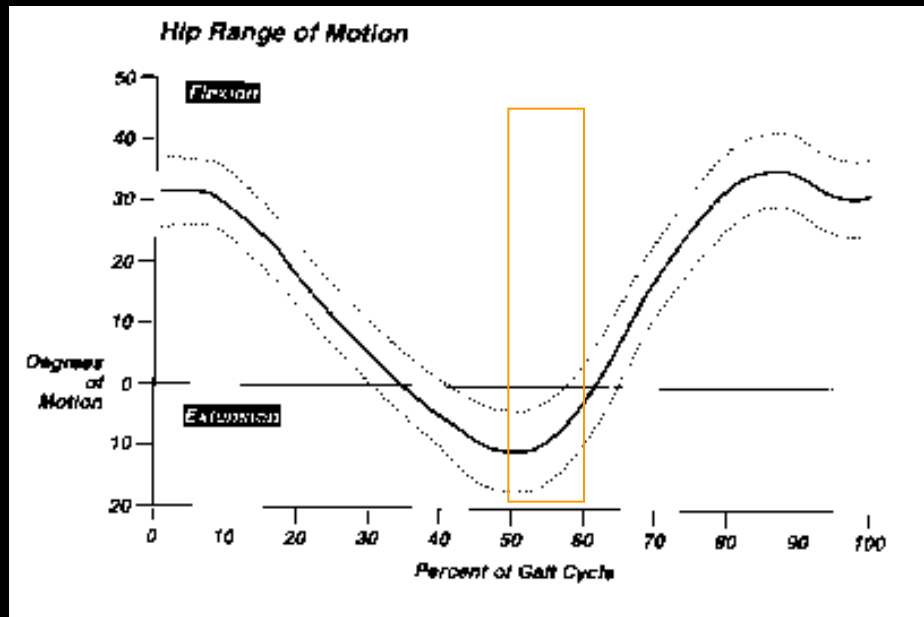




Hip Kinematic – Pre Swing

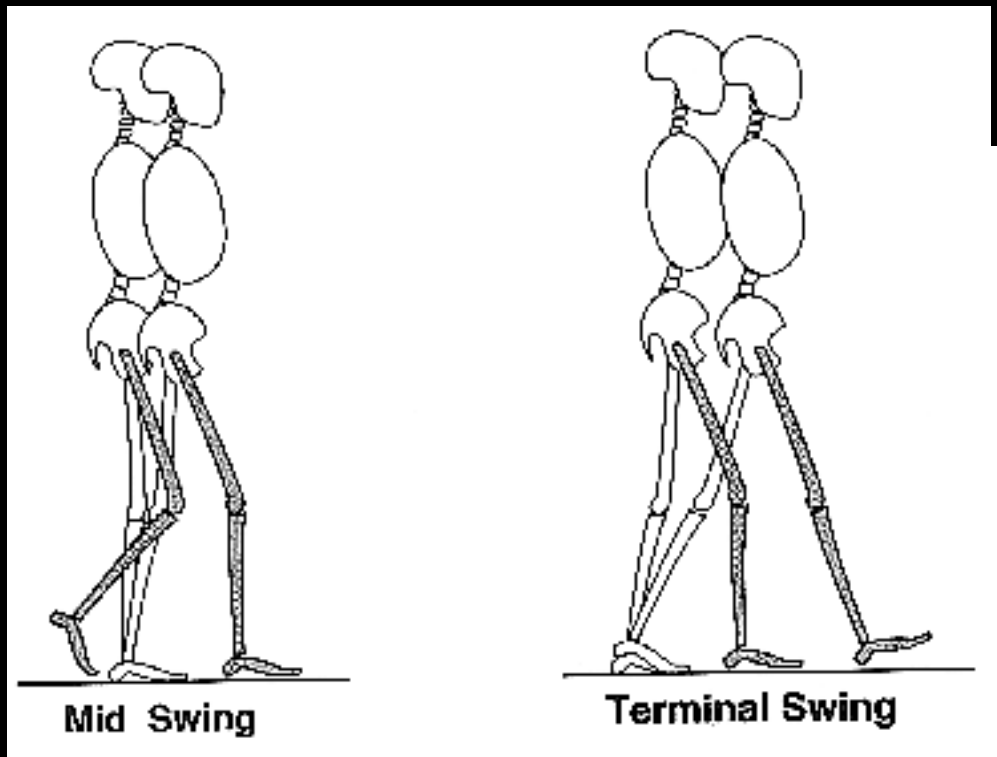
- Return to neutral

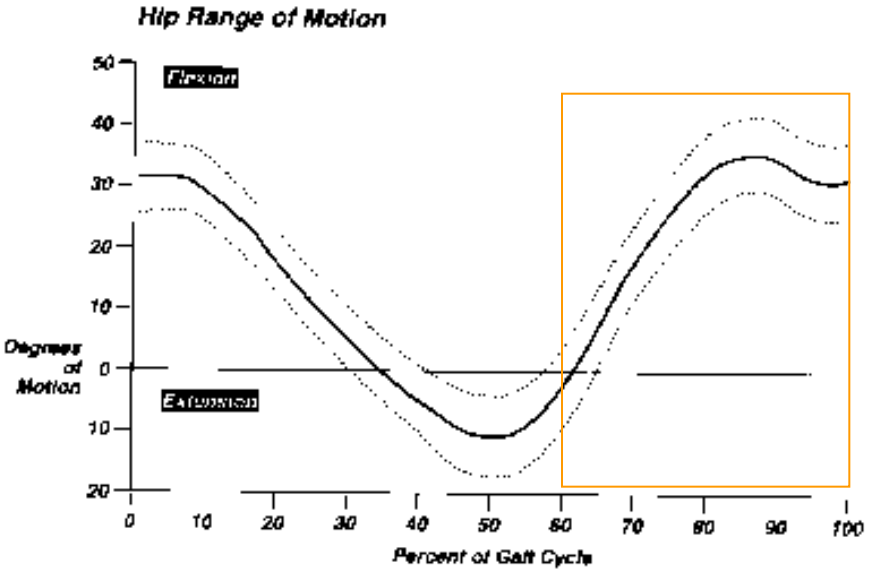




Hip Kinematic – Swing

- Max flexion at end of mid swing

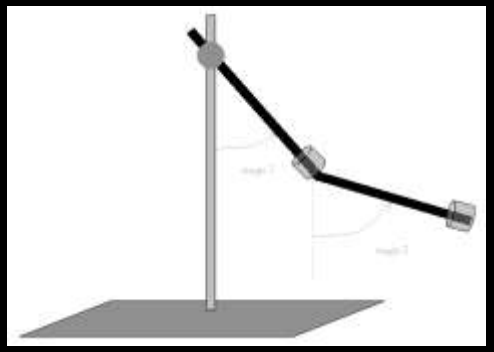




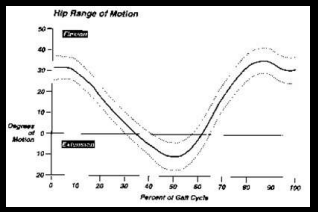
More definitions…

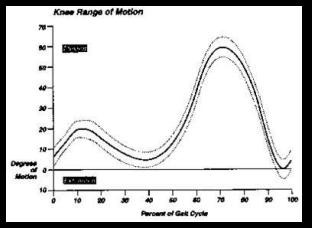
- Concentric = Energy lost
  - Joint motion in the same direction than the internal motion
  - Muscle activity with shortening
- Eccentric = Energy absorbed
  - Joint motion opposed to the internal motion
  - Muscle activity with lengthening

Double Pendulum



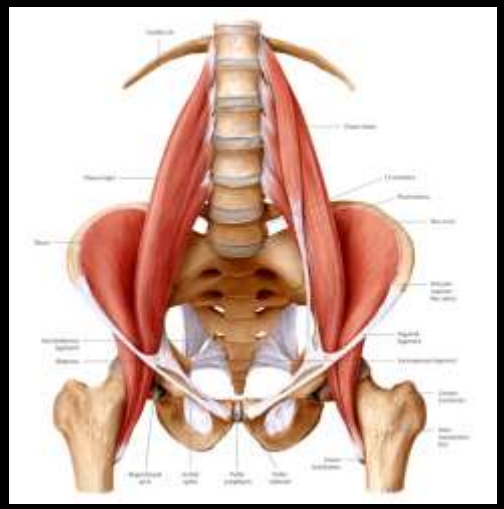
- Swing phase
- Motor:
  - Hip flexors
- <u>Passive</u> motion of knee and hip
  - Hip and knee flexion
  - Maximal flexion
    - Hip = 30°
    - Knee = 60°
  - Passive extension until stance phase





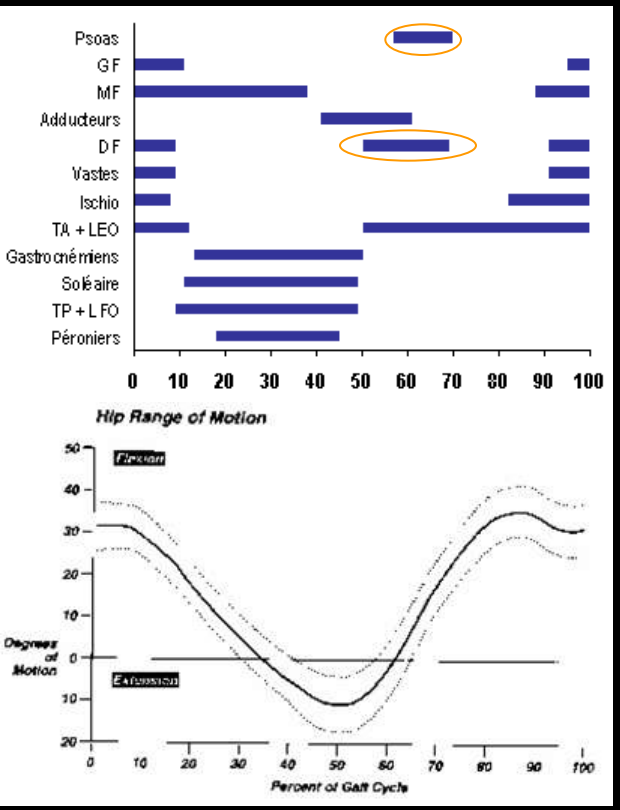
Flexors of the Hip

- Psoas (Ps)
  - Strongest hip flexor
  - Biarticular muscle



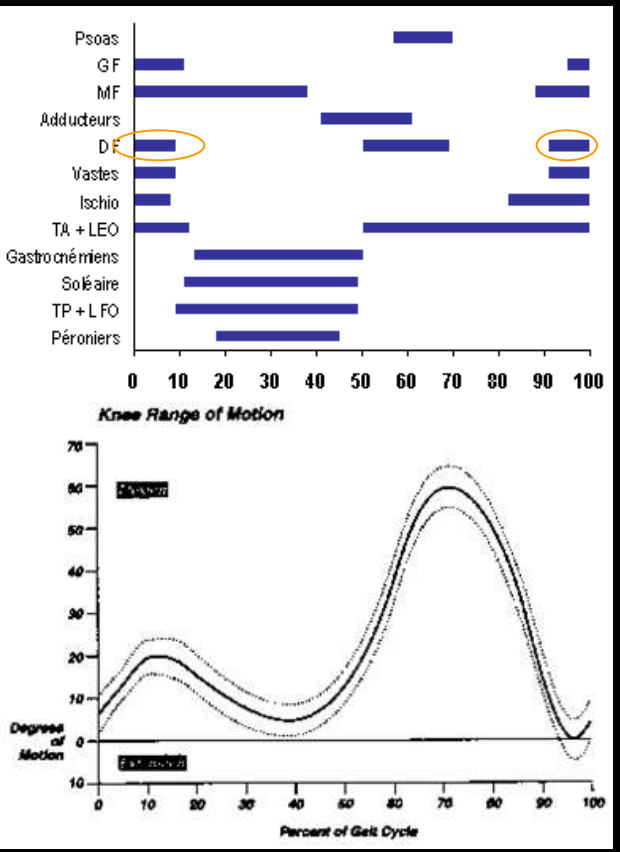
- Rectus Femoris (RF)
  - Hip flexor
  - Knee extensor (quadriceps)
  - Biarticular

Hip’s Flexors Function



Double Pendulum’s power

Extra role for Rectus Femoris

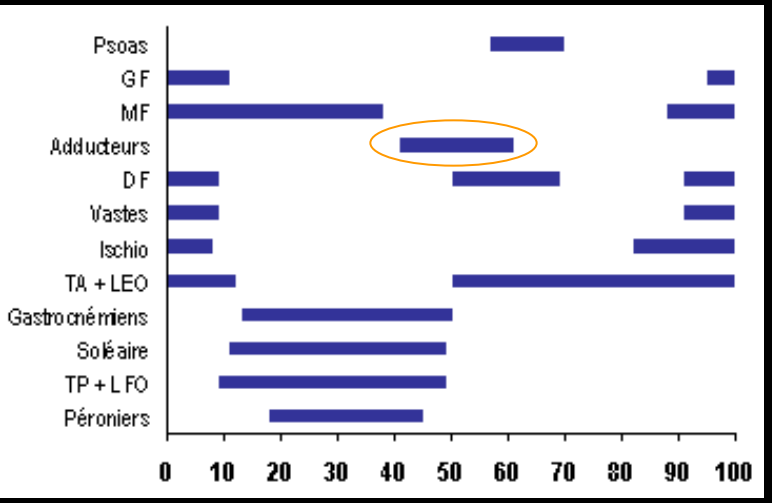


Control knee flexion (eccentric) to absorb impact

Terminal Swing

Loading Response

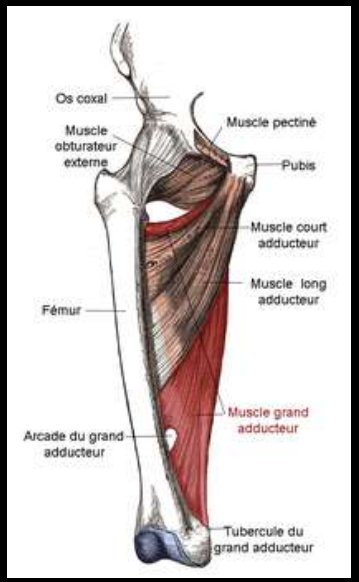
Adductors of the hip



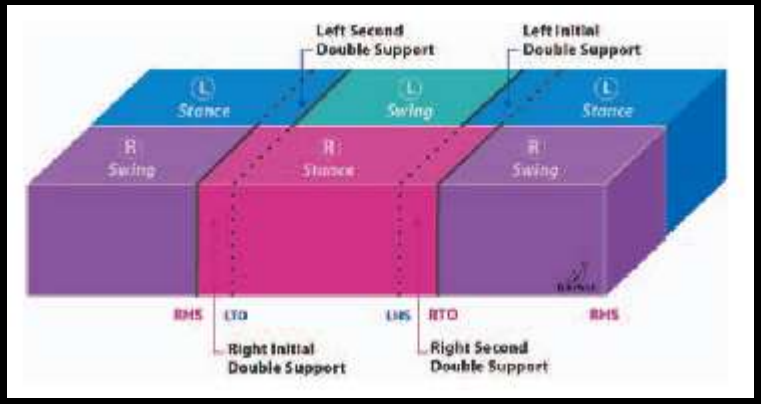
Adductor Longus

Adductor Magnus

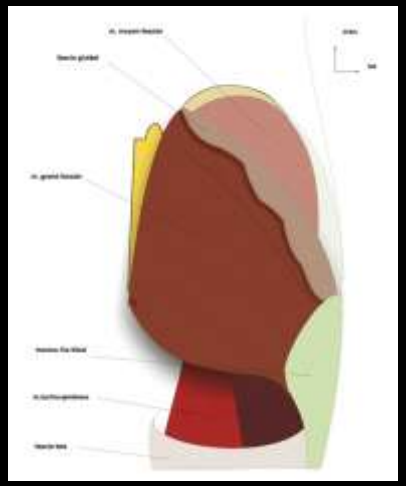
Adductor Brevis



Transfer of load before double support phase



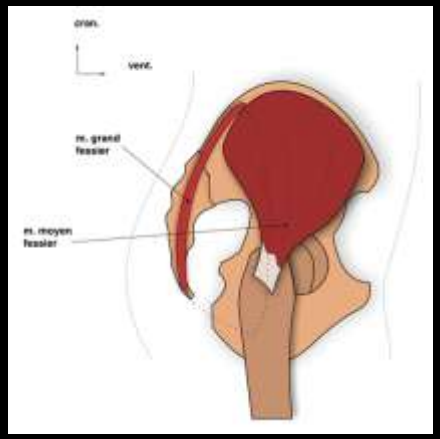
Gluteus Muscle

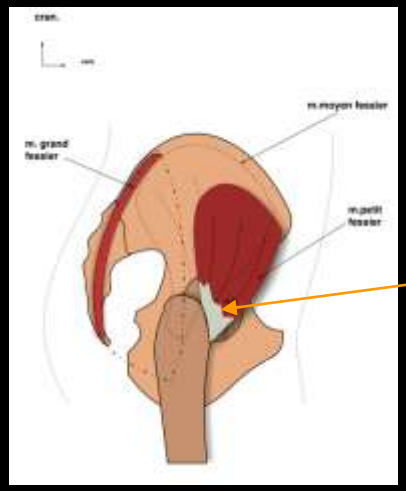


- Gluteus Maximus = extensor

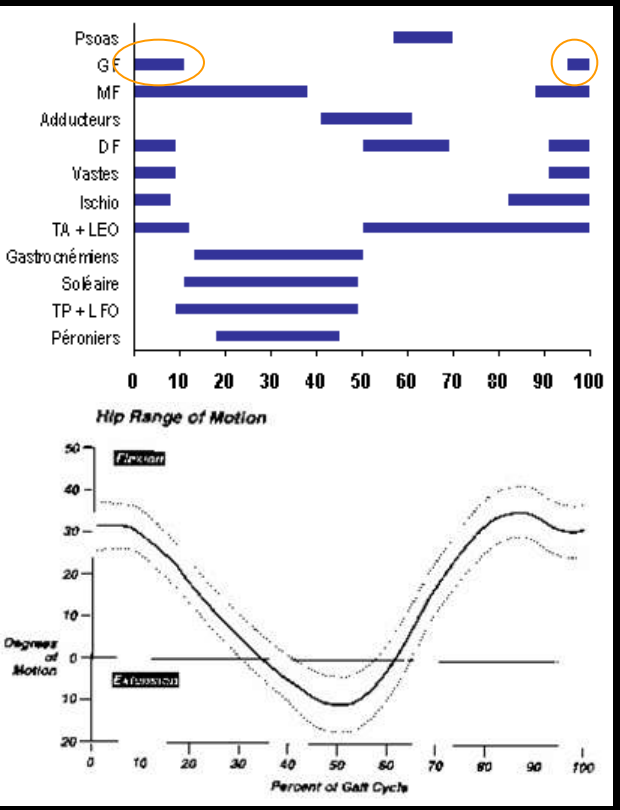
- Gluteus Medius
- Gluteus Minimus

= abductor

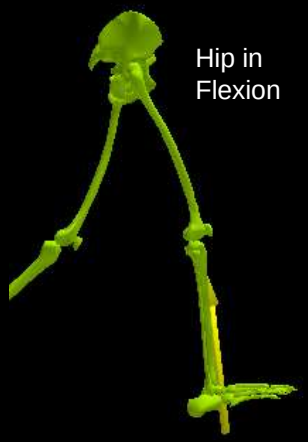




Gluteus Maximus Function

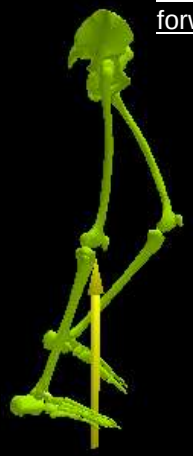


Slow down hip flexion



Hip in Flexion

Pull the upper body forward



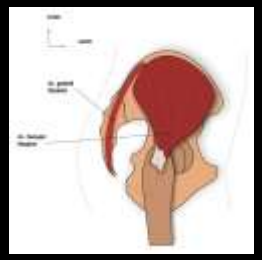
Loading Response

Mid Stance

Powerful hip extensor to pass the whole body weight over the foot in contact with the ground

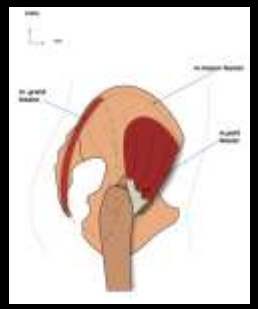
Gluteus Medius and Minimus

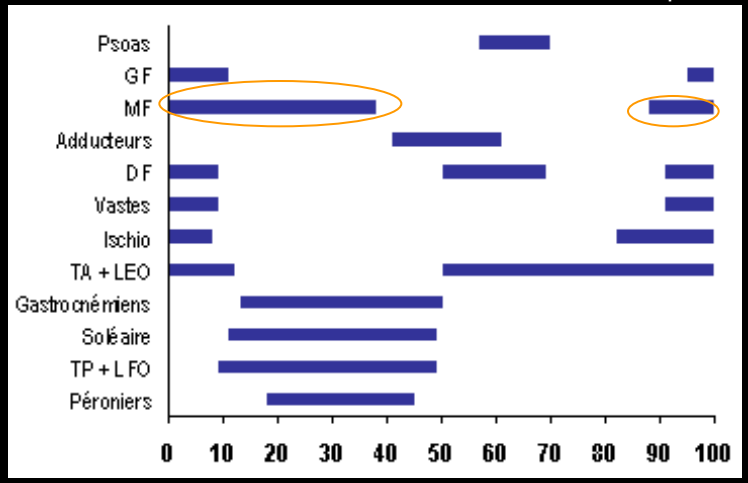
- Gluteus Medius:
  - Powerful muscle
  - Abductor for open chain
  - Pelvic stabilizer in closed chain (eccentric)



Anticipation

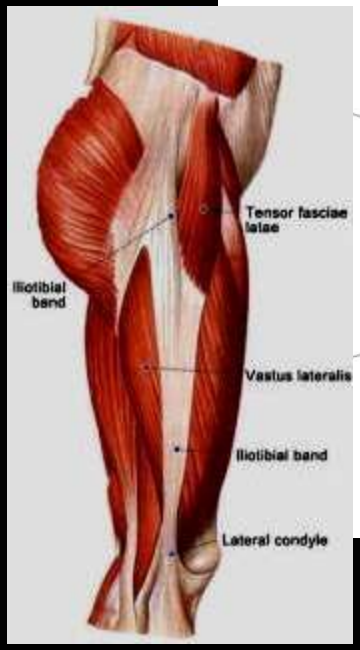
- Gluteus Minimus:
  - Mainly Abductor
  - Slightly Flexor

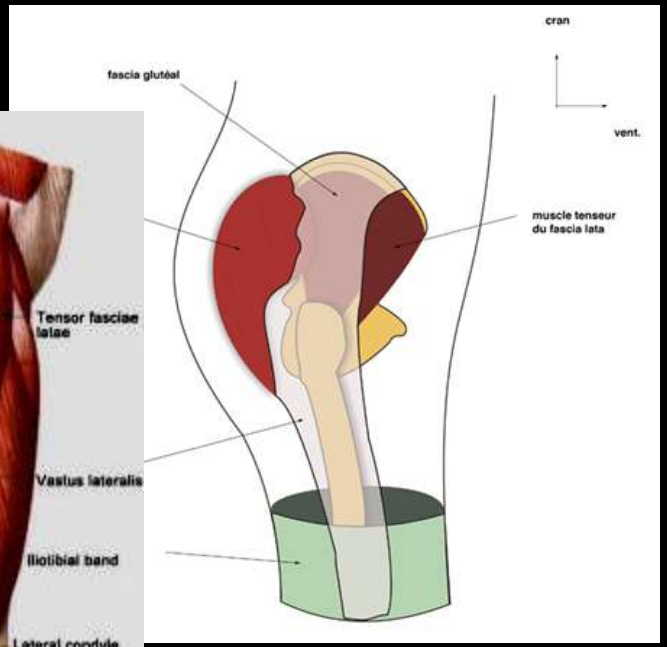


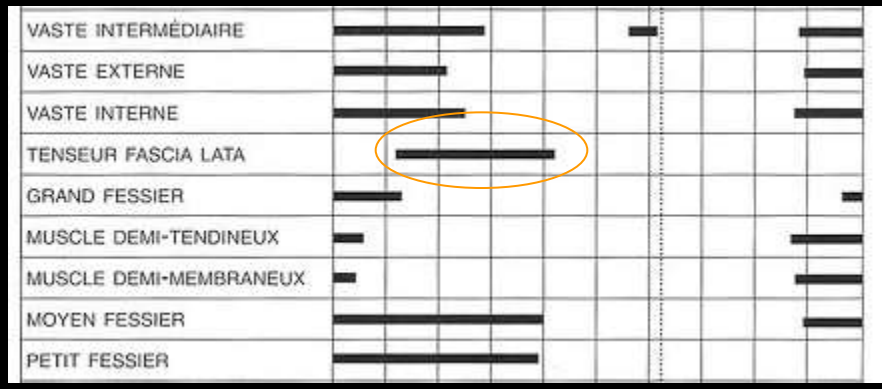


Tensor Fasciae Latae

- Hip and Knee Abductor
- Delayed action

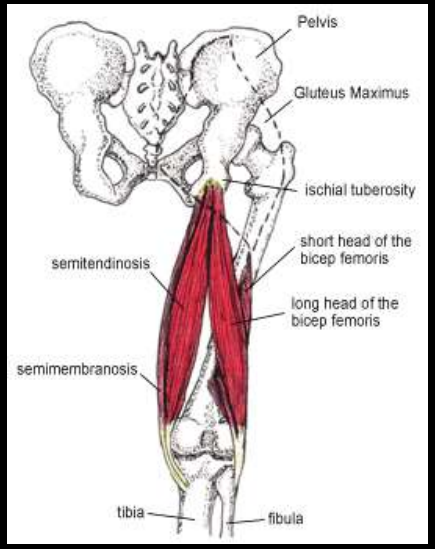




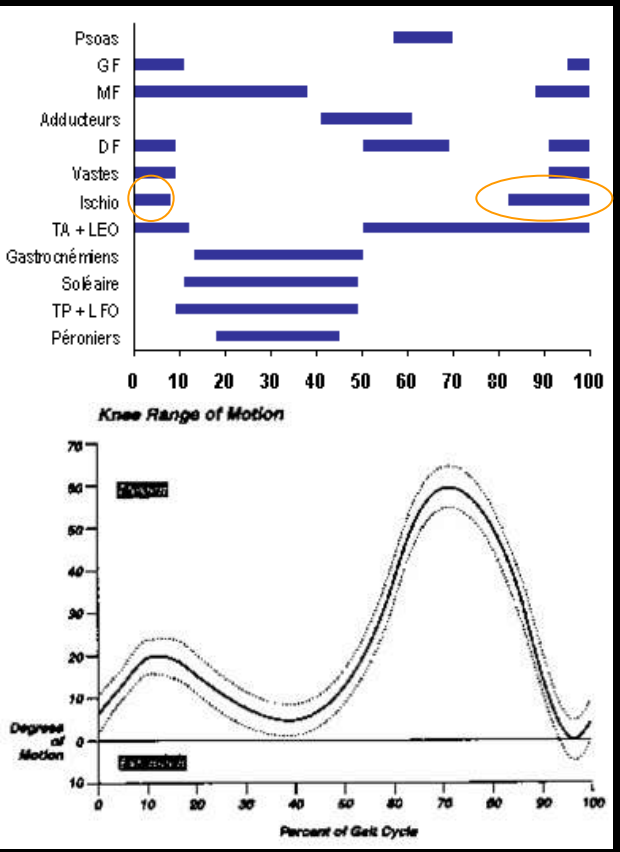


Hamstrings

- Medial = Semimembranosus + Semitendinosus
  - Hip Extensor
  - Knee Flexor
  - Internal Rotation of the Leg
- Lateral = Biceps femoris
  - Hip Extensor
  - Knee Flexor
  - External Rotation of the Leg



Hamstrings



Terminal Swing

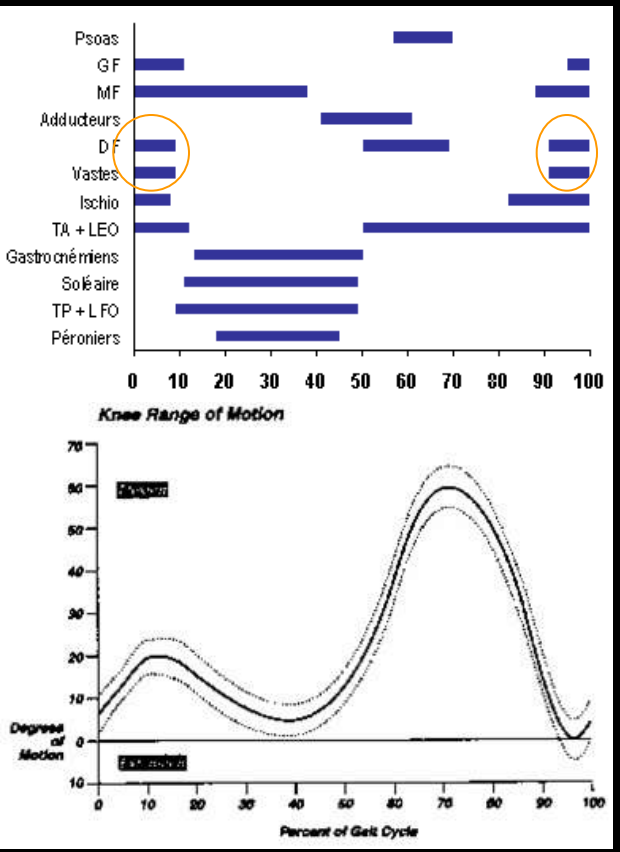
Loading Response

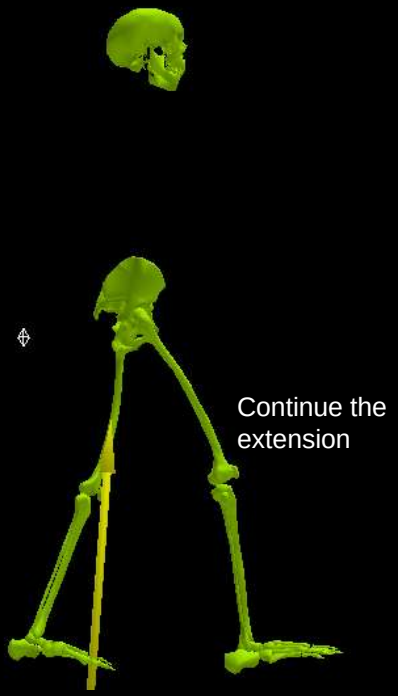
1. Slow down Knee Extension and Hip Flexion
2. Help Hip Extension

Hamstrings Stiffness

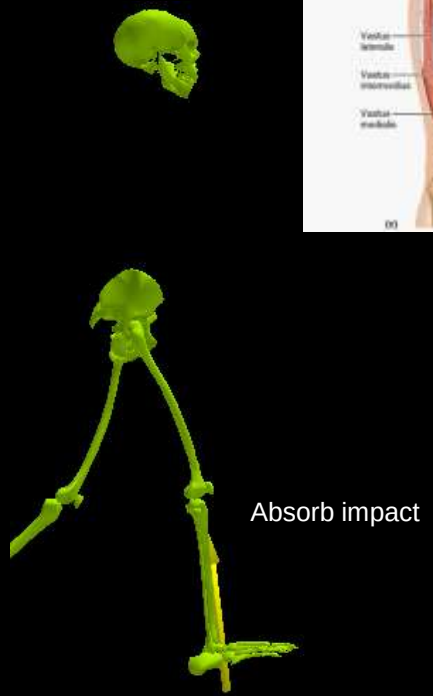
- Reduce step length
- Loading Response with tip toeing

Knee Extensors Function





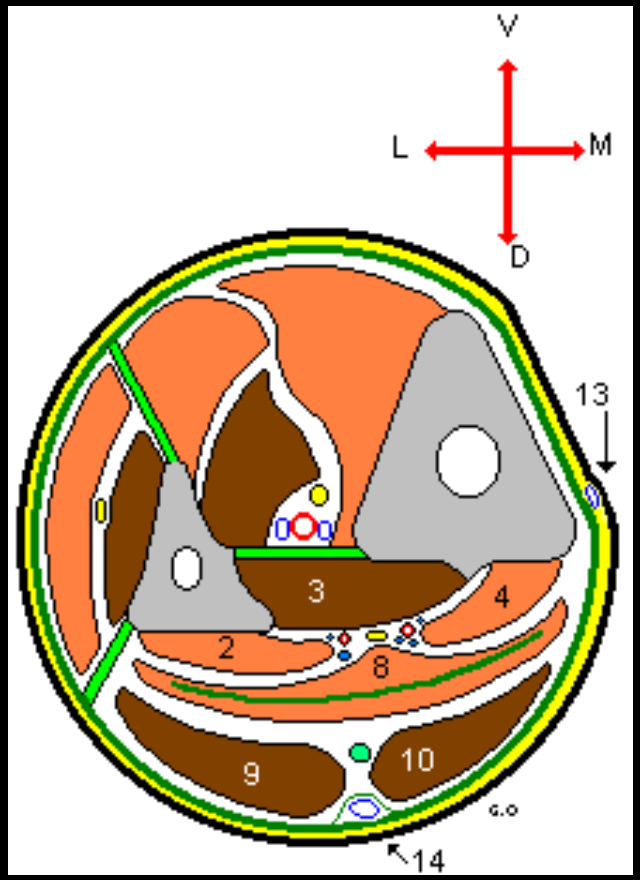
Terminal Swing



Load Response

1. Absorb impact (eccentric)
2. Concentric Knee Extension

Leg Compartments

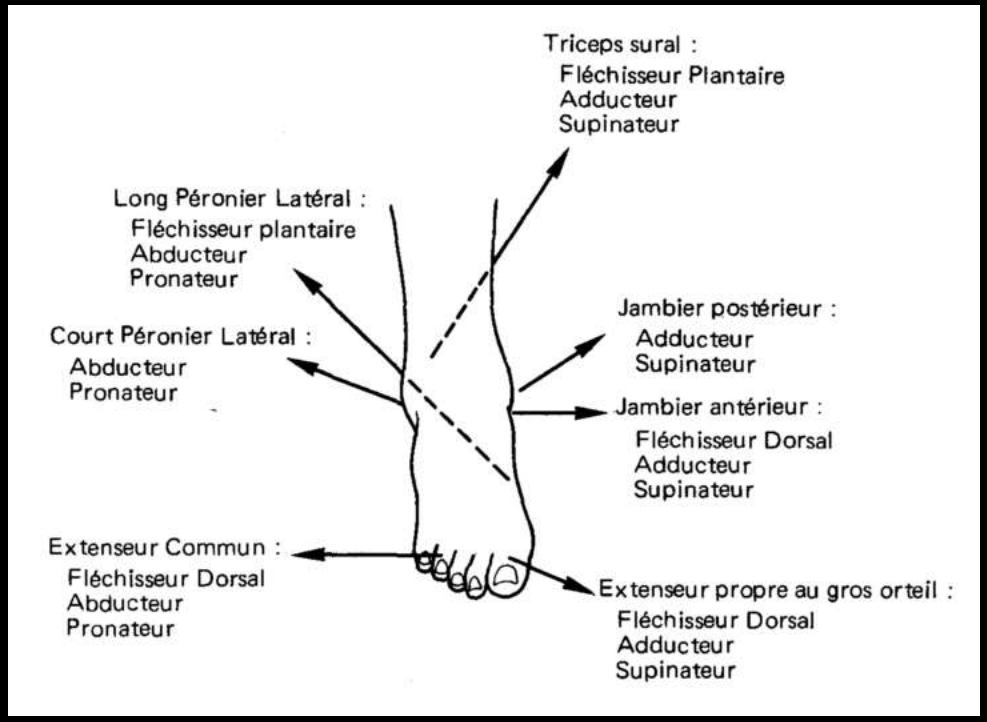


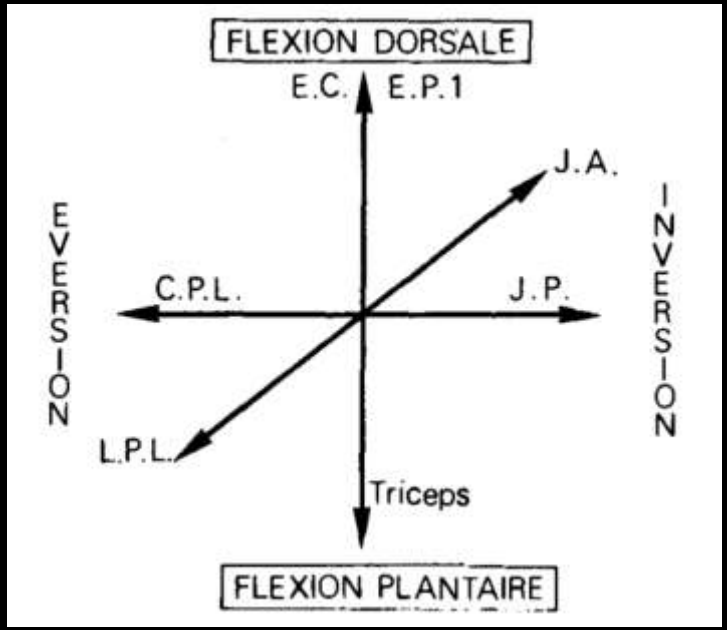
Anterior

Lateral

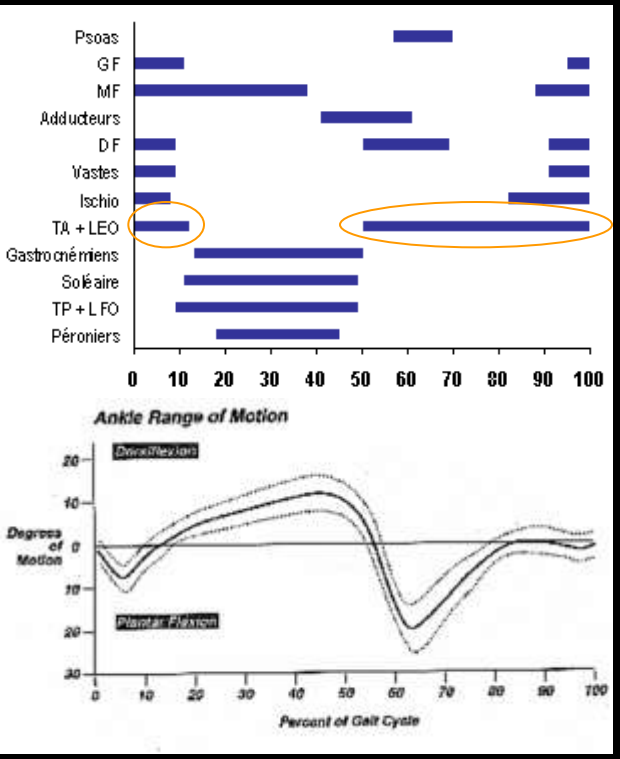
Posterior (2)

Foot ROM


Triceps sural :
Fléchisseur Plantaire
Adducteur
Supinateur
Long Péronier Latéral :
Fléchisseur plantaire
Abducteur
Pronateur
Court Péronier Latéral :
Abducteur
Pronateur
Jambier postérieur :
Adducteur
Supinateur
Jambier antérieur :
Fléchisseur Dorsal
Adducteur
Supinateur
Extenseur Commun :
Fléchisseur Dorsal
Abducteur
Pronateur
Extenseur propre au gros orteil :
Fléchisseur Dorsal
Adducteur
Supinateur

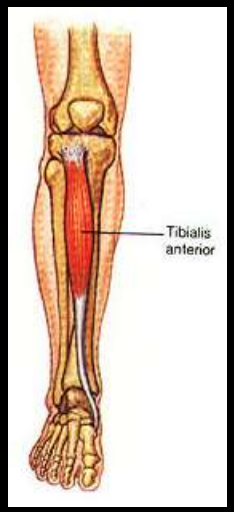

FLEXION DORSALE
E.C.
E.P.1
J.A.
EVERSION
INVERSION
C.P.L.
J.P.
L.P.L.
Triceps
FLEXION PLANTAIRE

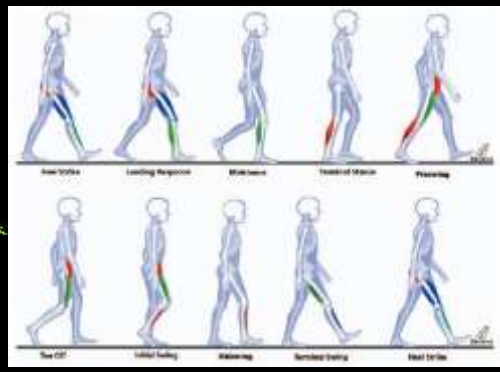
Anterior Compartment Function



Load Response

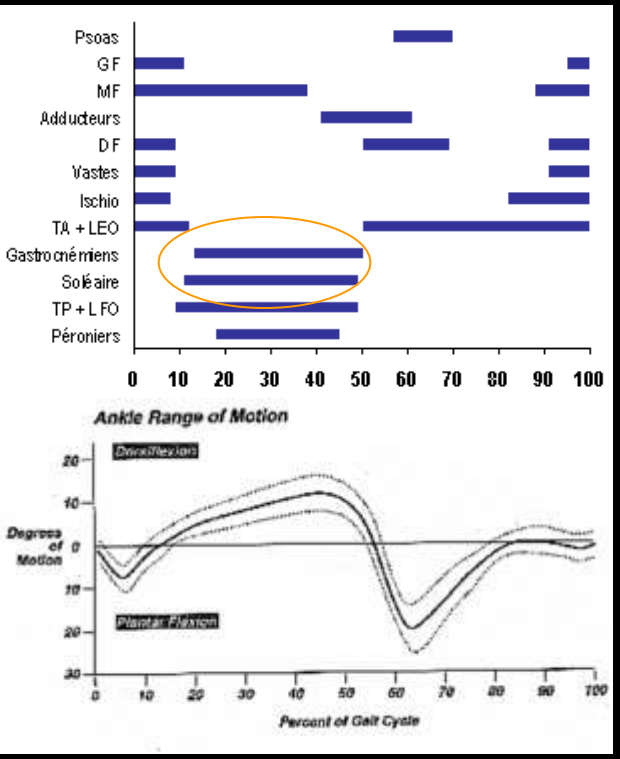
Initial Swing





1. Absorb load (eccentric)
2. Clearance (concentric)

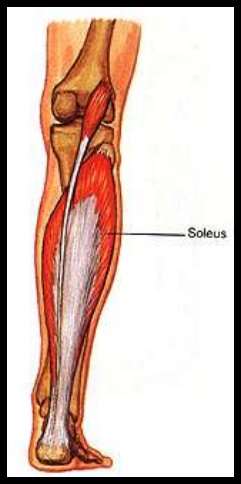
Superficial Posterior Compartment



1. Slow down Tibia Movement (Soleus)

2. Plantar propulsion (GCN)

Milieu et fin d'appui

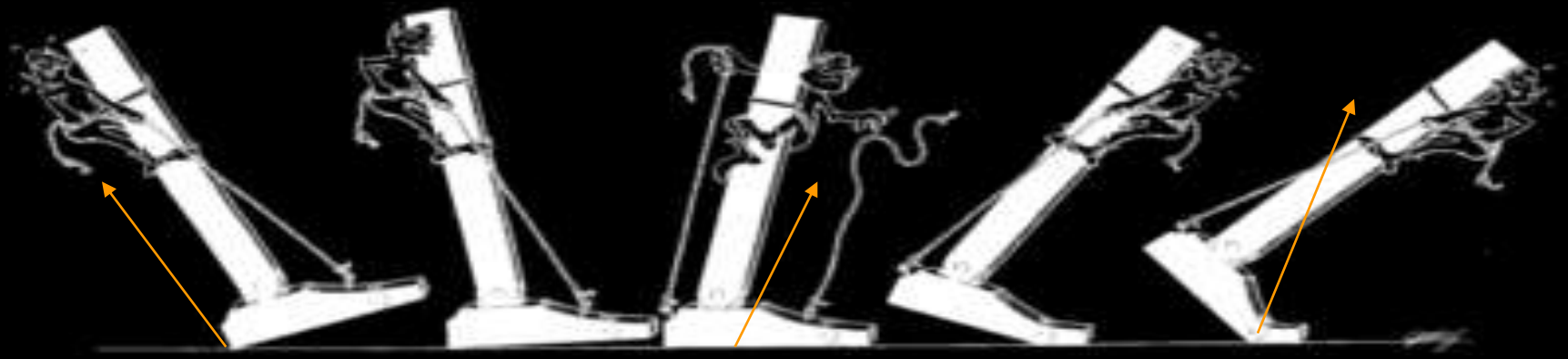


1. Slow down tibia (eccentric)
2. Plantar propulsion (concentric)

Soleus vs Gastrocnemius

- Soleus
  - Horizontal red fibers
  - Slow down tibia (eccentric)
- GCN
  - Vertical white fibers
  - Biarticulair
  - Plantar flexor

Rockers



1st Rocker = Heel

Ex moment = PF

Tib Ant

Eccentric

Absorb impact

2nd Rocker = Ankle

Ex moment = DF

Soleus

Eccentric

Ankle trunk forward

3rd Rocker = Toes

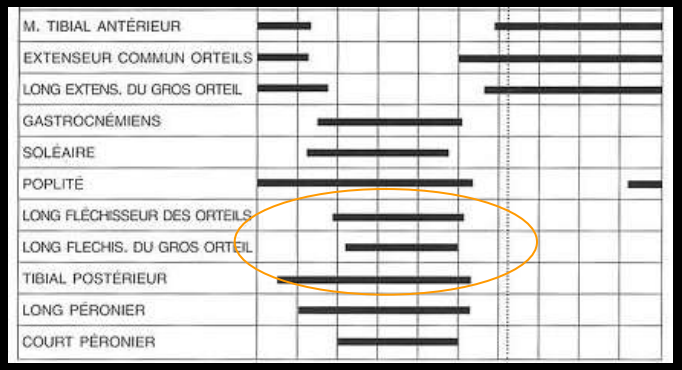
Ex moment = DF

GCN

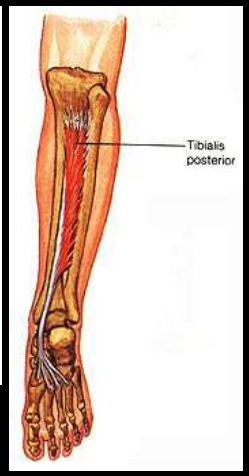
Concentric

Propulsion

Deep Posterior Compartment



- Tibialis posterior
  - Extensive insertion
  - Invert foot
  - Stabilize the foot in WB (Balance with the lateral compartment)

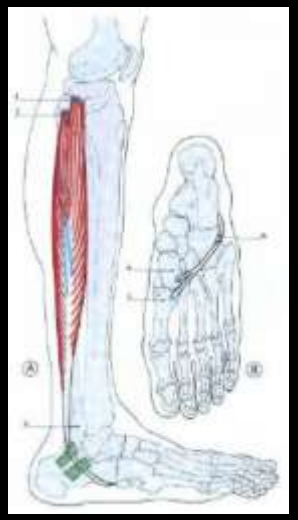


- Flexor hallucis longus
- Flexor digitorum longus

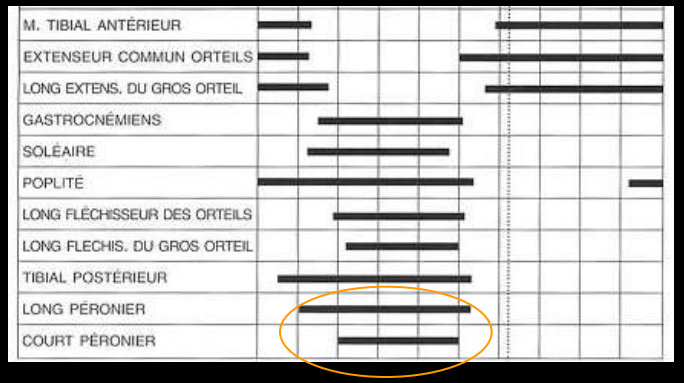
Ankle Plantar Flexion

Lateral Compartment

- Peroneus longus
  - Longer activity than PB
  - Support longitudinal arch
  - Plantar flex 1st ray (pronation)



- Peroneus brevis
  - Evert foot

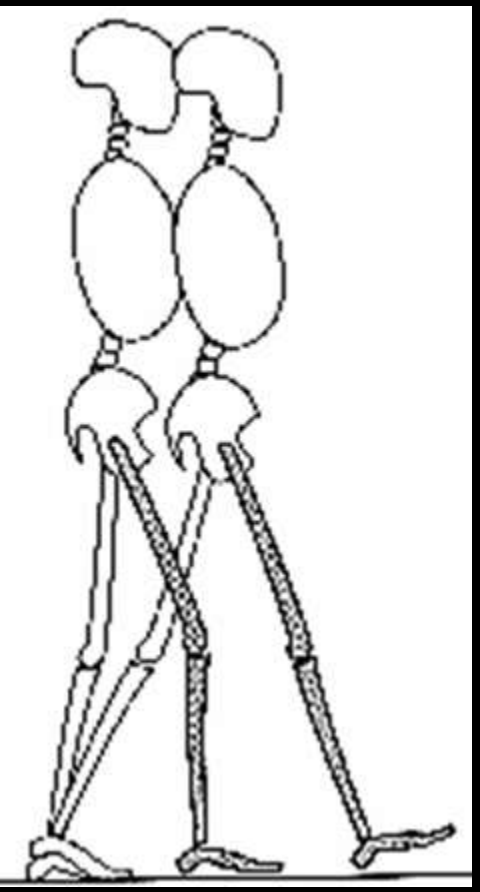


Ankle Plantar Flexion

Gage's prerequisites for normal gait

1. Prepositioning of the foot
2. Clearance of the foot swing
3. Stability in stance
4. Adequate step length
5. Energy conservation

End of swing phase

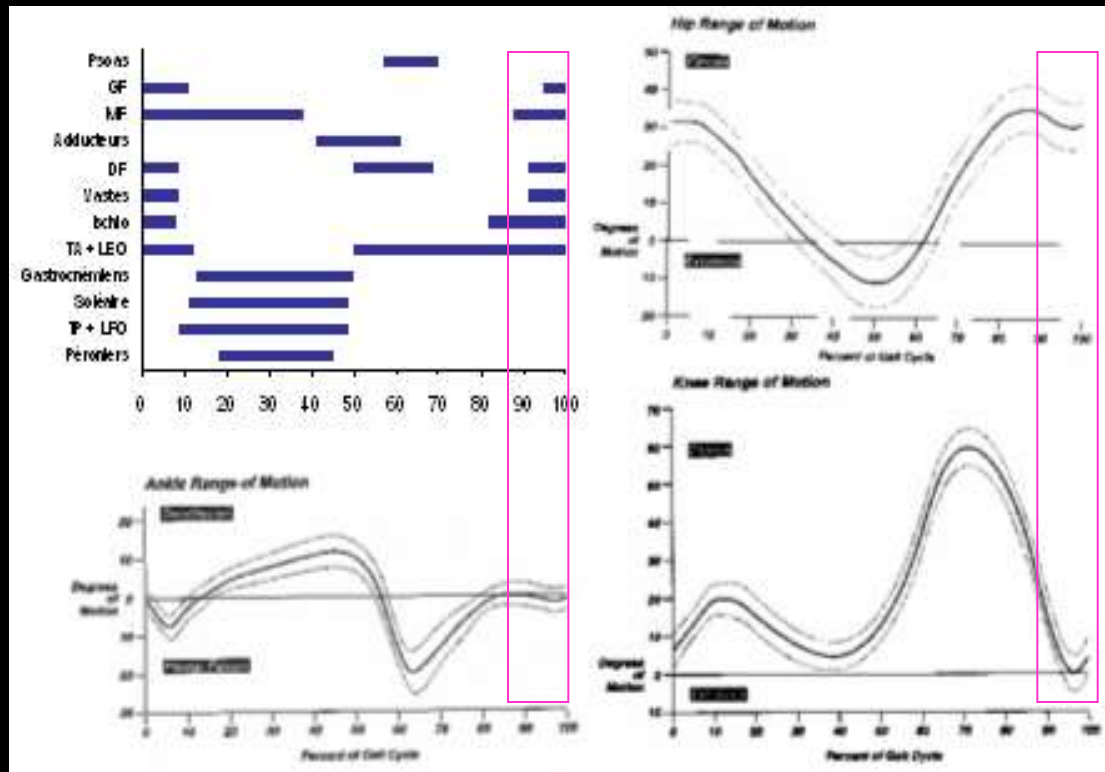


Preparation for initial contact

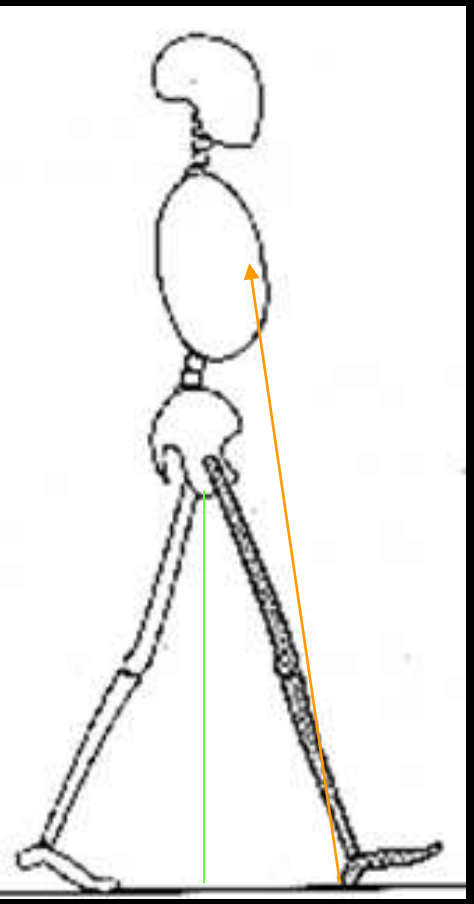
Slow down (eccentric) the pendulum (GMx+H)

Prepare to absorb choc

Tib Ant present the heel in neutral position



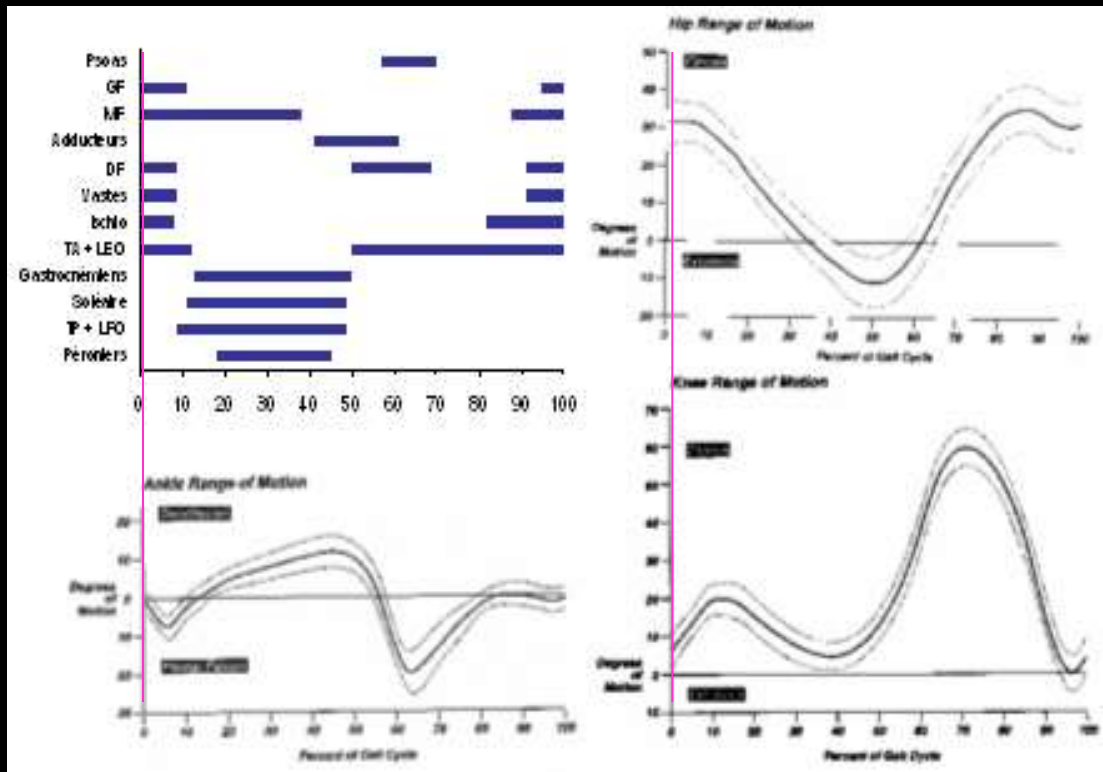
Initial contact



Reaction to GRF

Continue the previous phase

Slow down the momentum of the whole body: GMx, H, Tib Ant



Loading Response

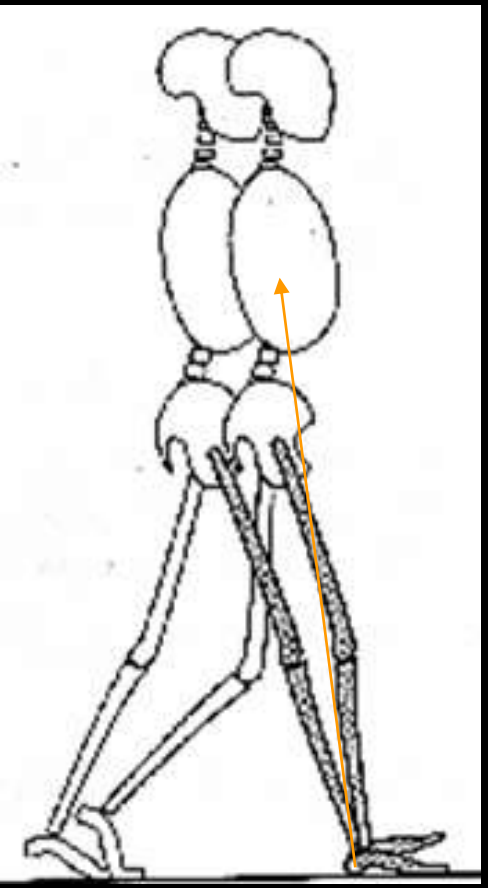
Impact phase

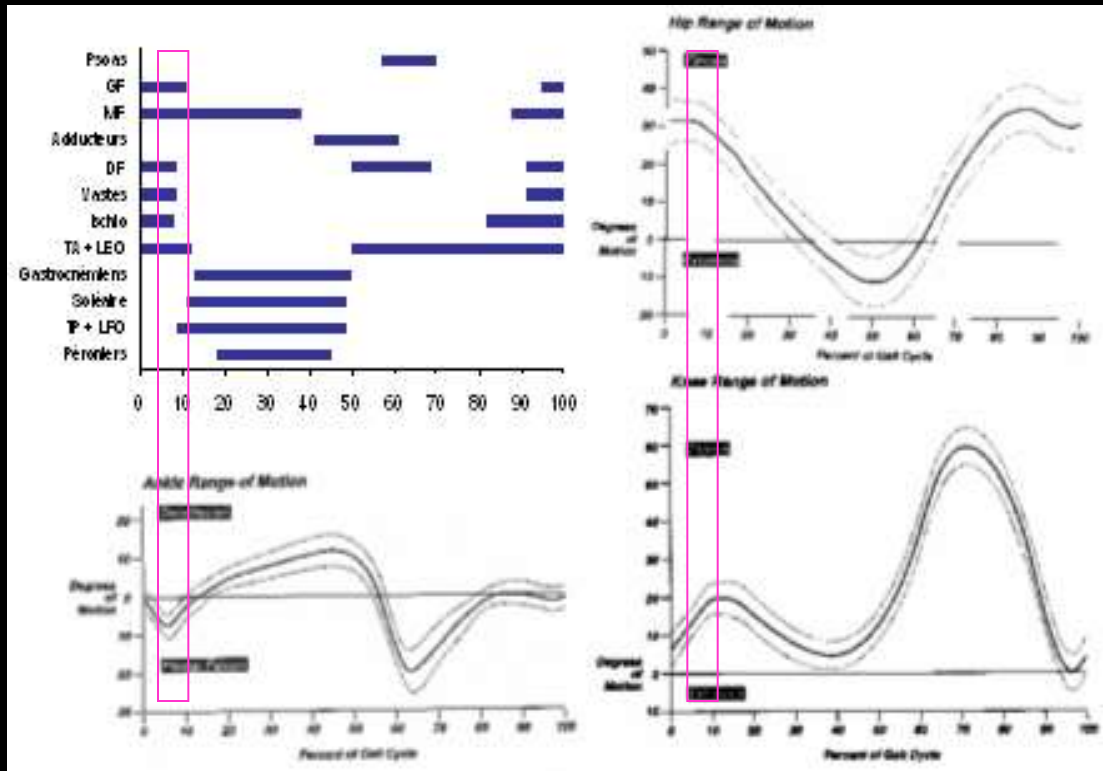
Plantar flexion and knee flexion

Tib Ant control PF and knee extensors control KF (eccentric)

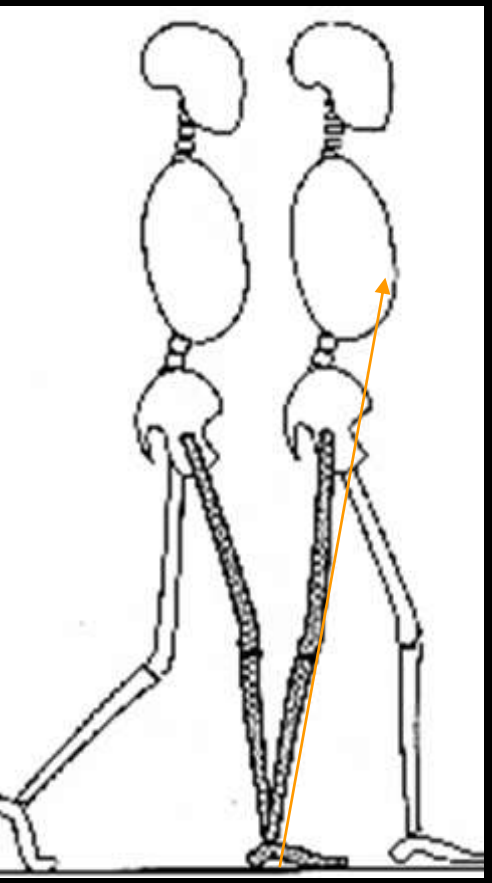
GMx to pull the upper body forward (concentric)

GMd stabilize the pelvis





Mid Stance



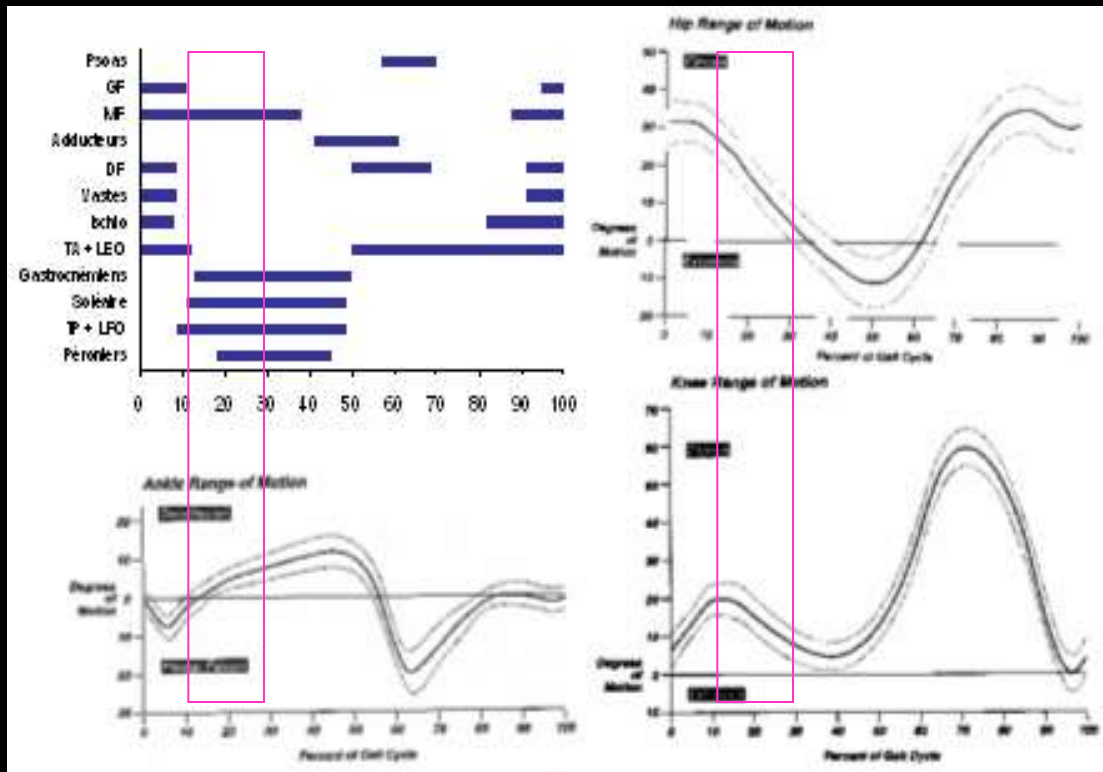
Stability phase

GMd stabilize the pelvis

The foot flat on the ground don't need the action of the Tib Ant

Tib Post and P are balanced

Soleus slow down the dorsal flexion (eccentric)



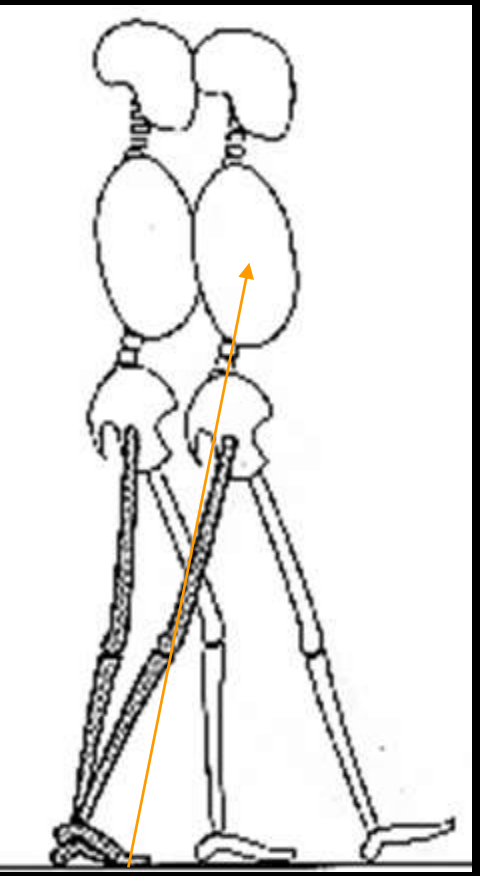
Terminal Stance

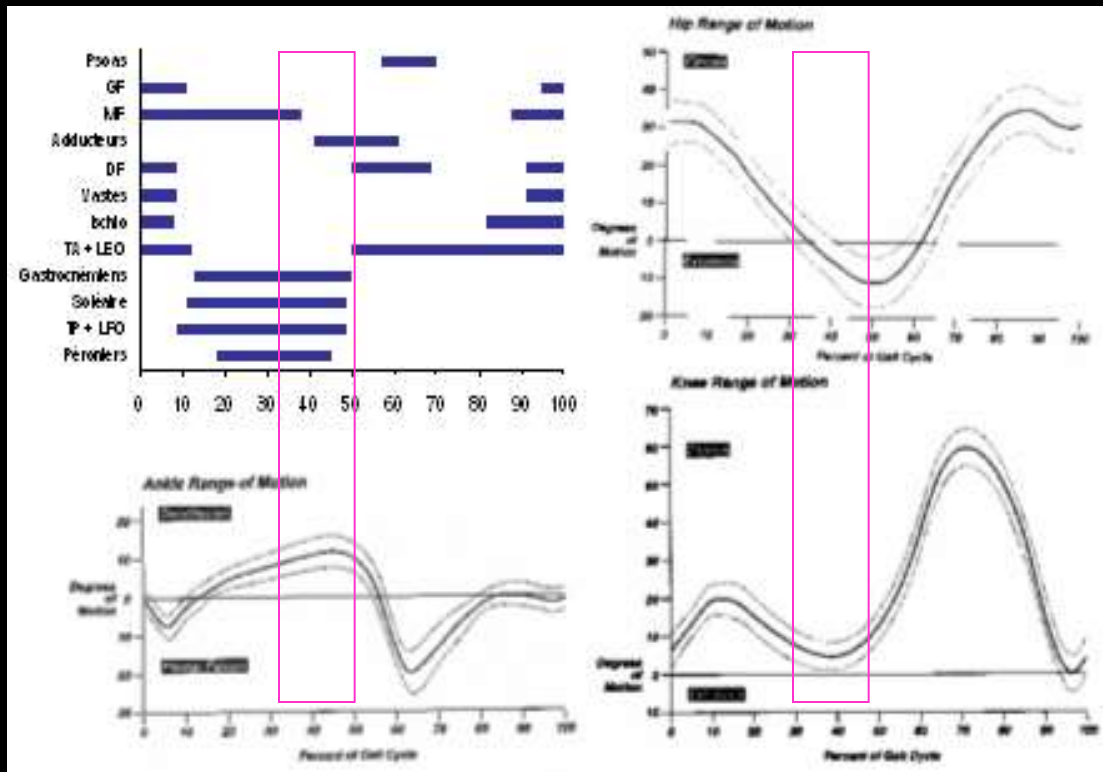
Prepare for load transfer

Centre of gravity in front of the ground contact

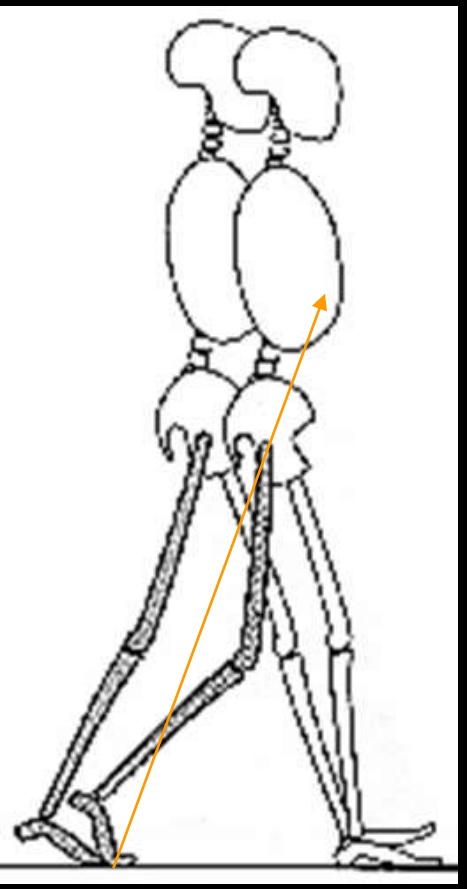
Knee locked in extension

Soleus slow down tibial advancement (eccentric)





Pre Swing

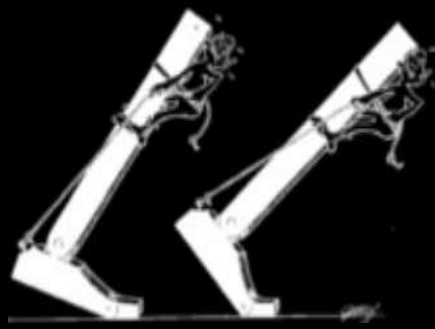


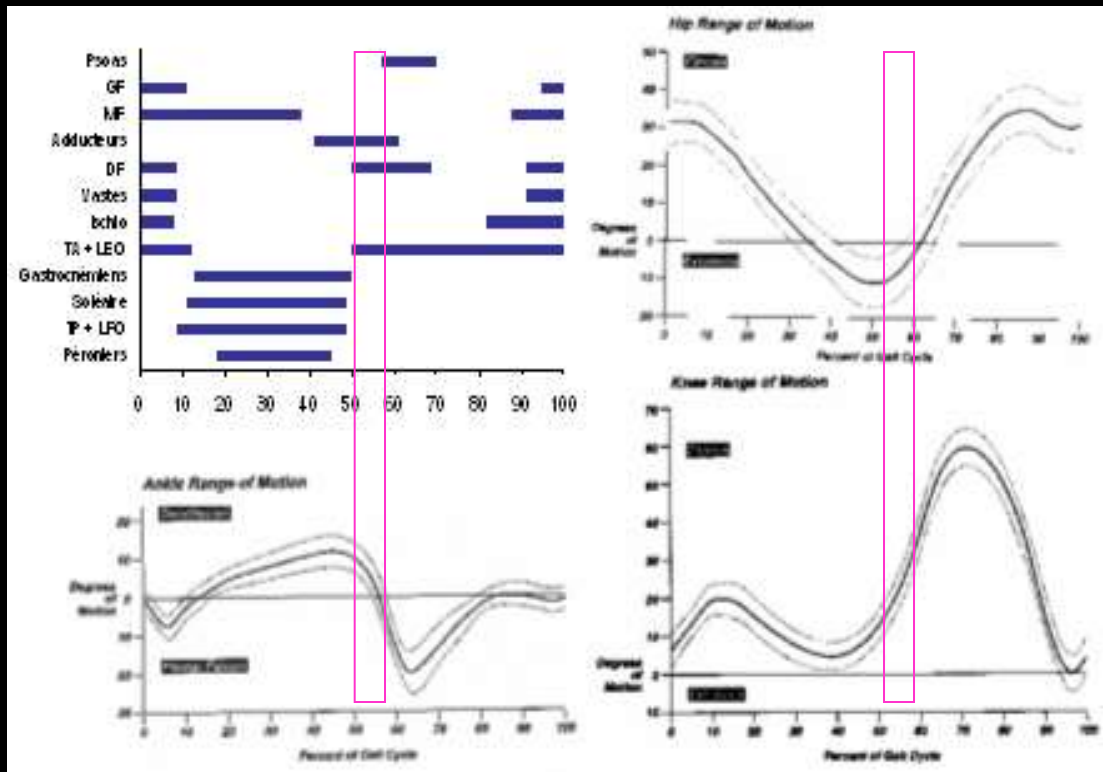
Load Transfer

Concentric action of GCN helped by the load transfer

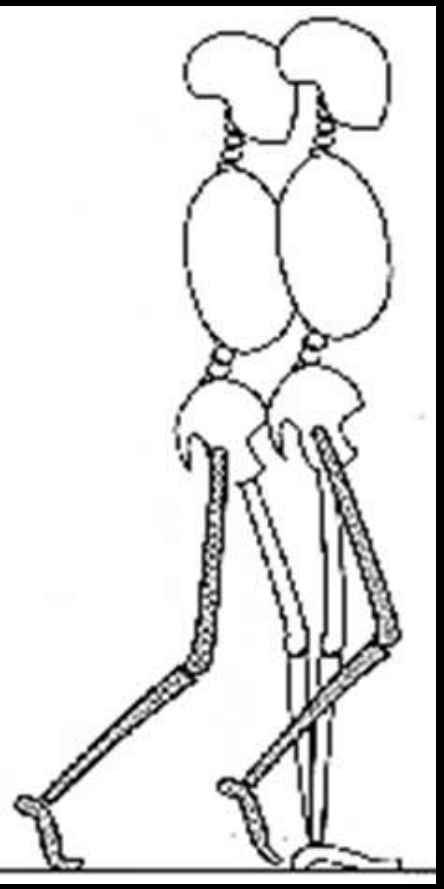
RF slow down the knee flexion (eccentric)

Plantar propulsion leading to the hip flexion





Initial Swing

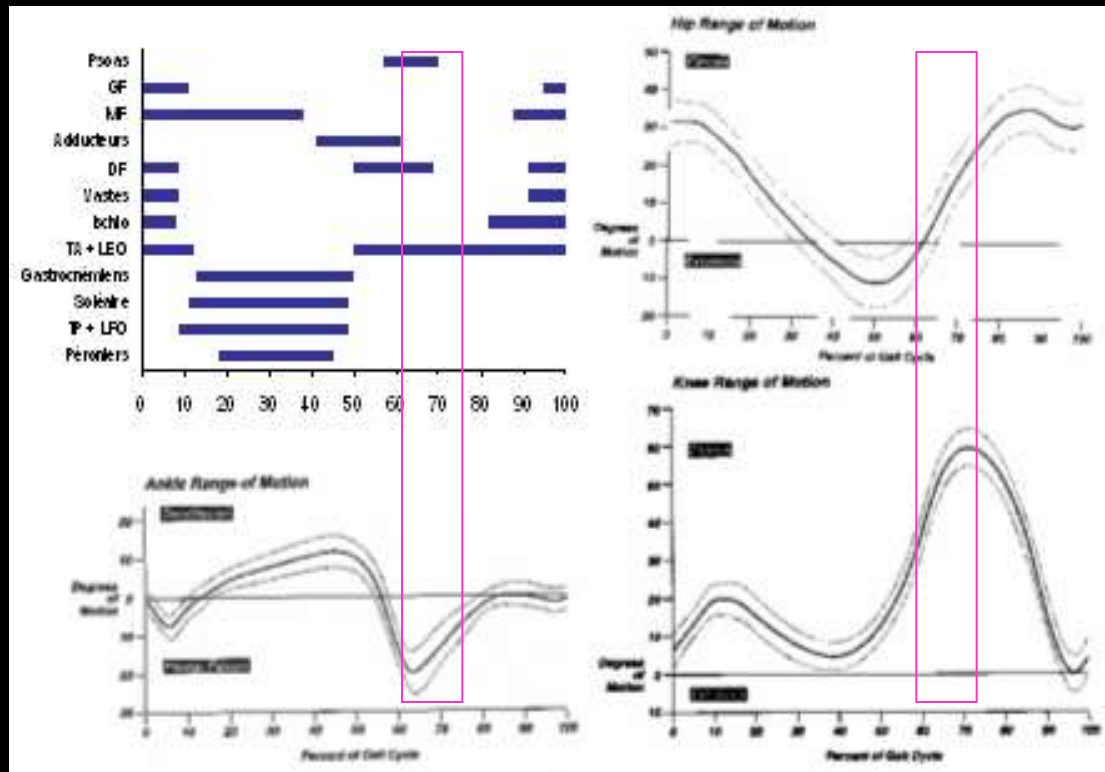


Clearance

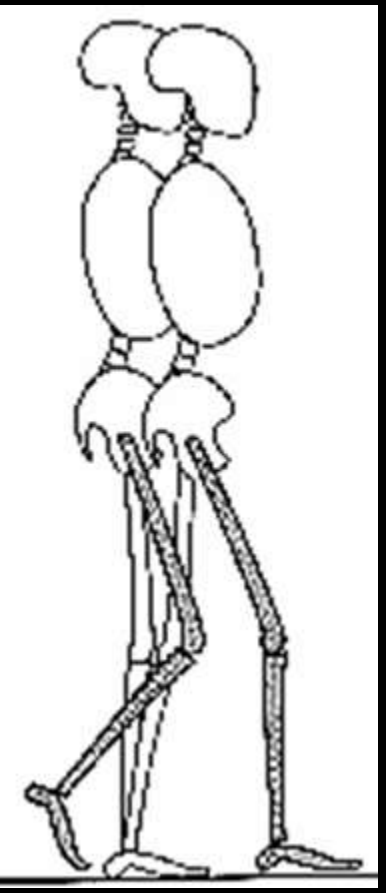
Huge and fast activity of the hip flexors (Psoas)

Concentric action for Tib Ant

Double pendulum: Knee flexion



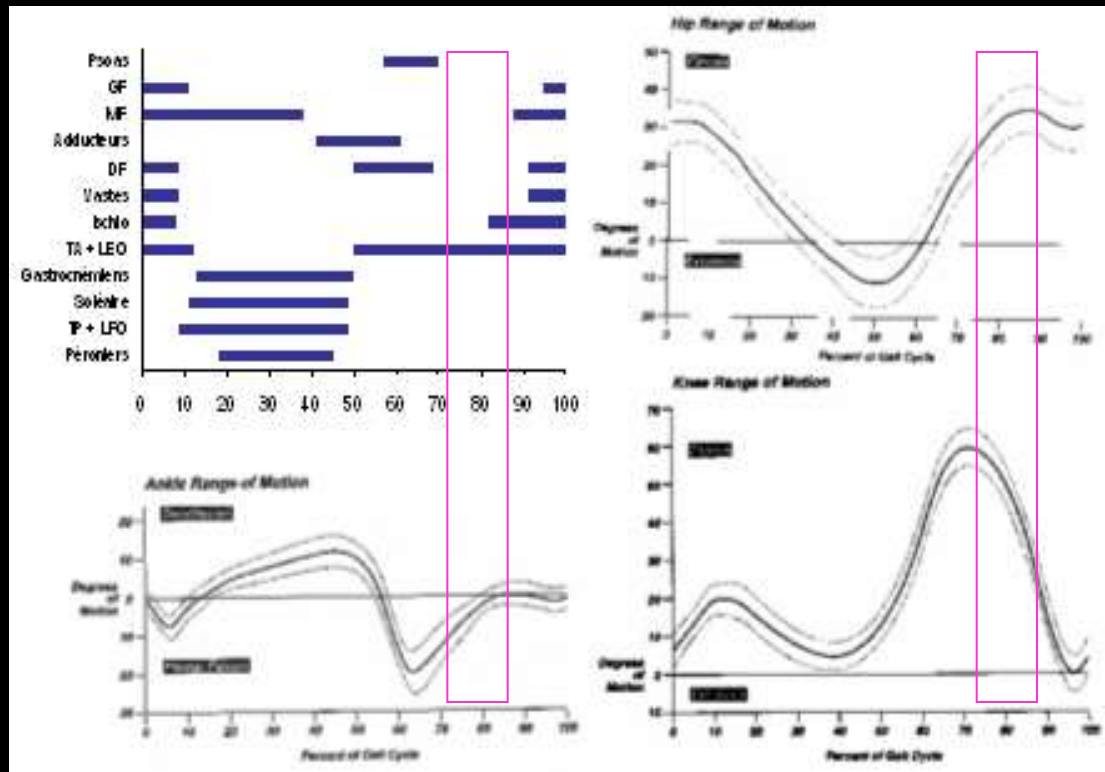
Mid Swing



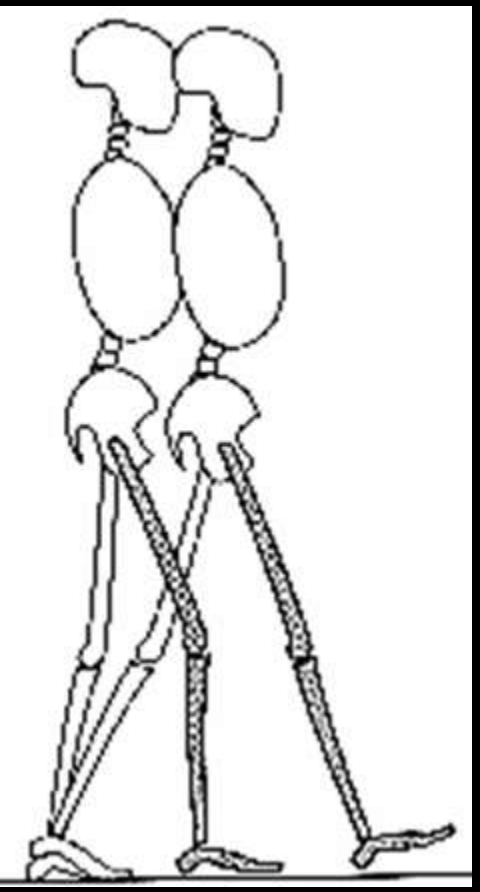
Double pendulum

Passive phase

Only Tib Ant is active



Terminal Swing

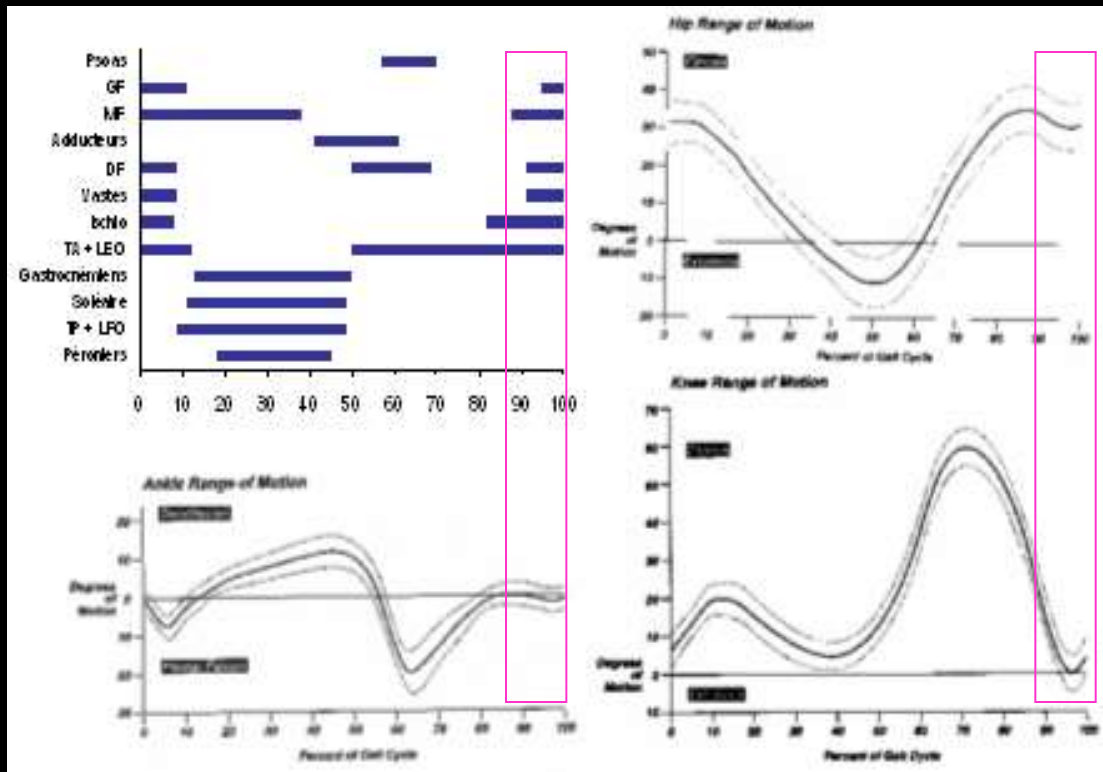


Preparation for initial contact

Slow down (eccentric) the double pendulum (GMx+H)

Prepare to absorb impact

Tib Ant present the heel in neutral position



Thank you…