



INDIANA UNIVERSITY

DEPARTMENT OF PHYSICAL THERAPY
SCHOOL OF HEALTH AND REHABILITATION SCIENCES

Indiana Chapter APTA

Central District Meeting

Thursday, April 16, 2009

OBSERVATIONAL GAIT ANALYSIS*

Identifying Normal Gait

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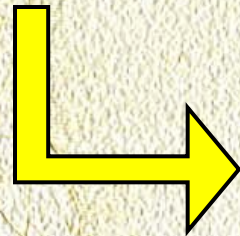
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*Primary resource: The Pathokinesiology Service & The Physical Therapy Department at Rancho Los Amigos National Rehabilitation Center. *Observational Gait Analysis*. Downey, CA: Los Amigos Research and Education Institute; 2001. (<http://www.larei.org/publicat.htm>)

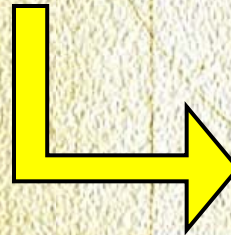
Walking Gait

Most Common Human Movement

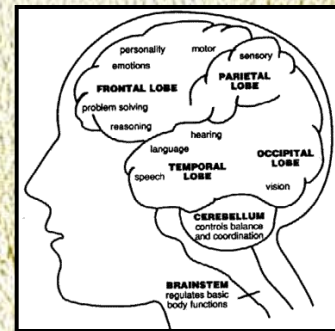
Walking is inherent,



yet hard to learn,



yet subconscious



- Ψ May become altered with injury or disease
 - Understand Normal to understand Abnormal

Normal Walking Gait

What Exactly Does Normal Mean?

- Ψ Within a person, **highly repeatable** pattern or sequence of limb motions
 - Stride-to-stride & day-to-day variability of walking pattern is moderately low
- Ψ Across several Normal people, **↑ variability**
 - Differences in Ht, Wt, Age, Sex, Cadence, etc.
 - Normalize to reduce between subject variability

Now we have a less variable, more universal pattern we can call Normal

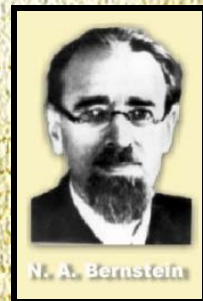
Normal Walking Gait

However, it's never that simple...

- Ψ It's possible to achieve same movement pattern from many different combinations of muscles
 - Coordinating muscles acting across many joints

“The coordination of a movement is the process of mastering redundant DoFs... its conversion to a controllable system” (Bernstein, 1967)

- Ψ Control system is highly **flexible** & **adaptable**
- Ψ Can accomplish same goal in many ways



Bernstein N. *The coordination and regulation of movements*. London: Pergamon, 1967.

Normal Walking Gait

- Ψ This motor redundancy is good, but it confounds assessment in that there is no unique solution to a given movement pattern

So what do we do now?

Consider Common Purpose of Walking

- Ψ Move body safely & efficiently across ground

Achieved by **5 functions/tasks** during each stride

- All 5 tasks must be performed within the anatomical/internal constraints of the body

Normal Walking Gait

1) **Generate Mechanical Energy**

- Velocity: maintain or ↑

2) **Absorb Mechanical Energy**

- Shock, stability, or ↓ vel

3) **Maintain Support of HAT**

- Prevent collapse of LE during stance

4) **Maintain Upright Posture**

- Balance of total body; level head

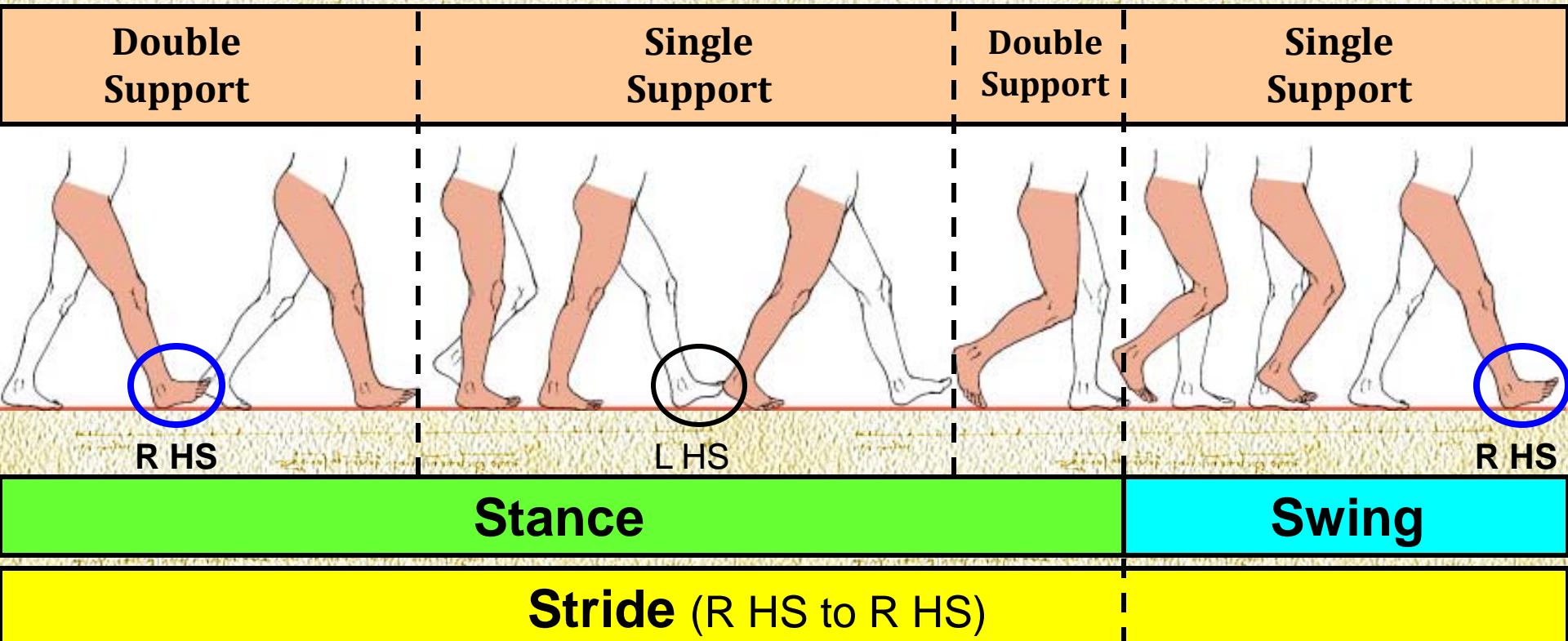
5) **Control Foot Trajectory**

- Safe ground clearance
- Gentle heel to toe landing

**Gait
Cycle**

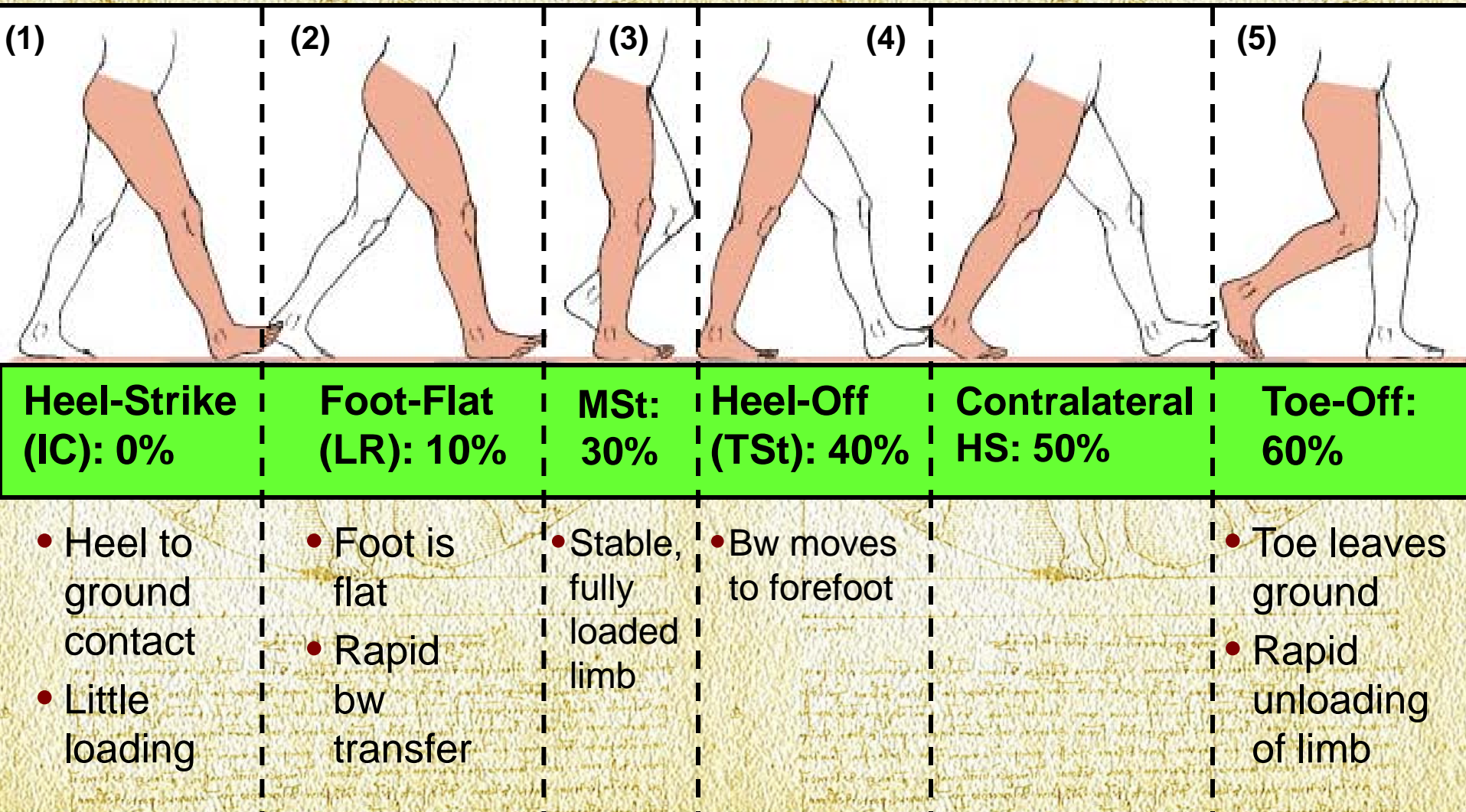
Normal Gait Cycle

- Ψ Heel-Strike to next ipsilateral Heel-Strike
- Ψ Subdivide into **Stance & Swing** phases
 - Stance = period of limb-ground contact
 - Swing = period of no limb-ground contact

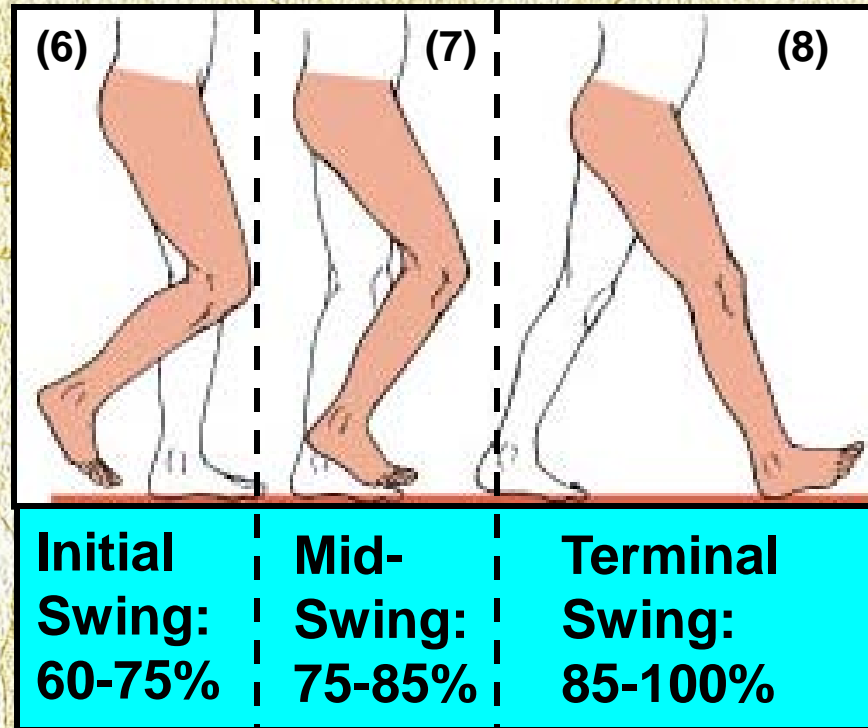


Stance Phase

Subdivide **Stance** & **Swing** for further analysis



Swing Phase



- Thigh advances

- Foot leaves ground

- Thigh advances

- Foot clears ground

- Knee extends

- Limb slows down

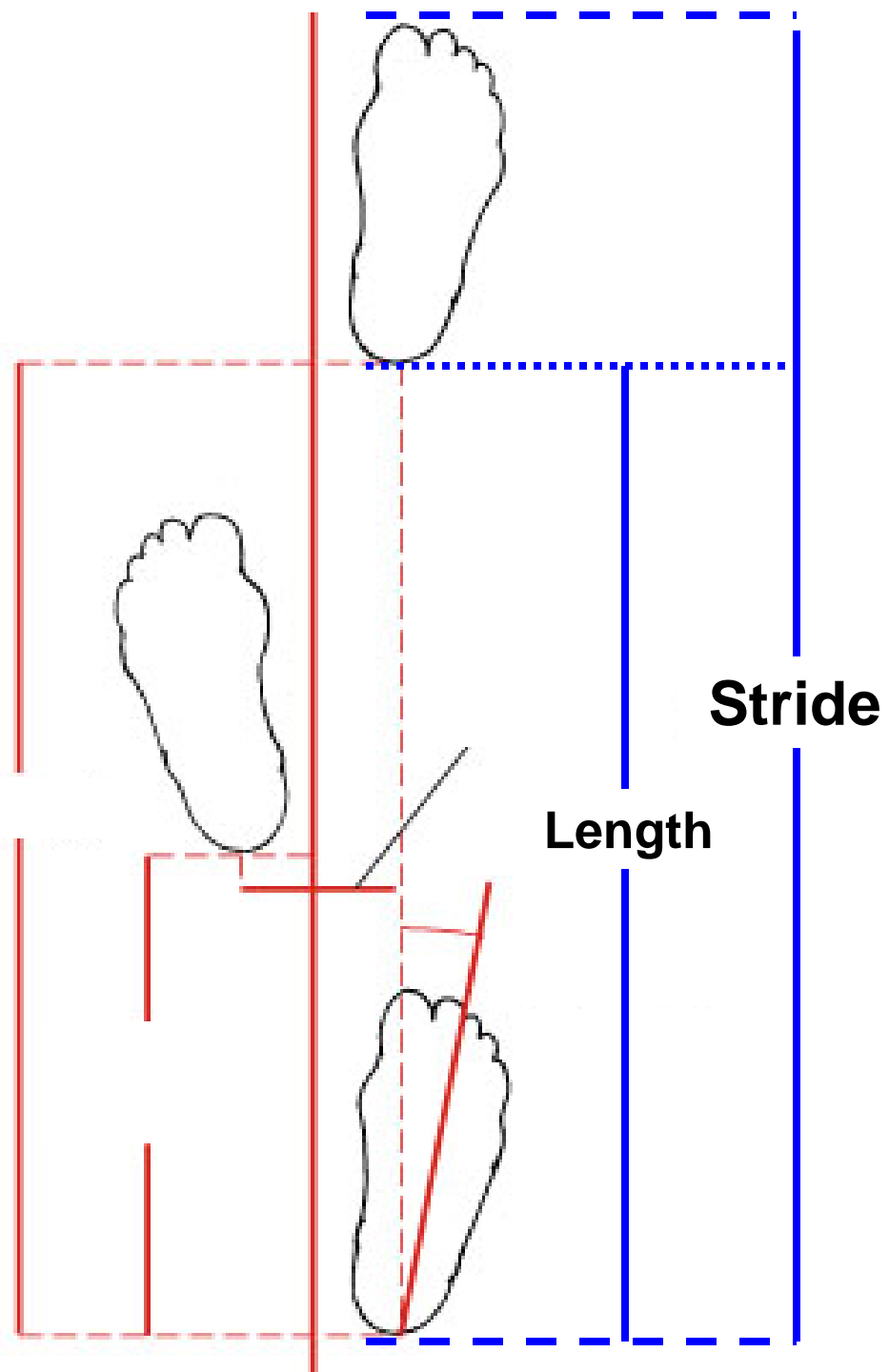


KINEMATICS OF LOCOMOTION

Gait Parameters

Displacement

- Ψ **Stride** – includes movement of both limbs during a gait cycle
 - Contains 2 steps
- Ψ **Stride Length** – distance from HS of 1 foot to next HS of same foot
- Ψ **Mean: 56" (1.40 m)**
 - Male: 1.48 m
 - Female: 1.30 m

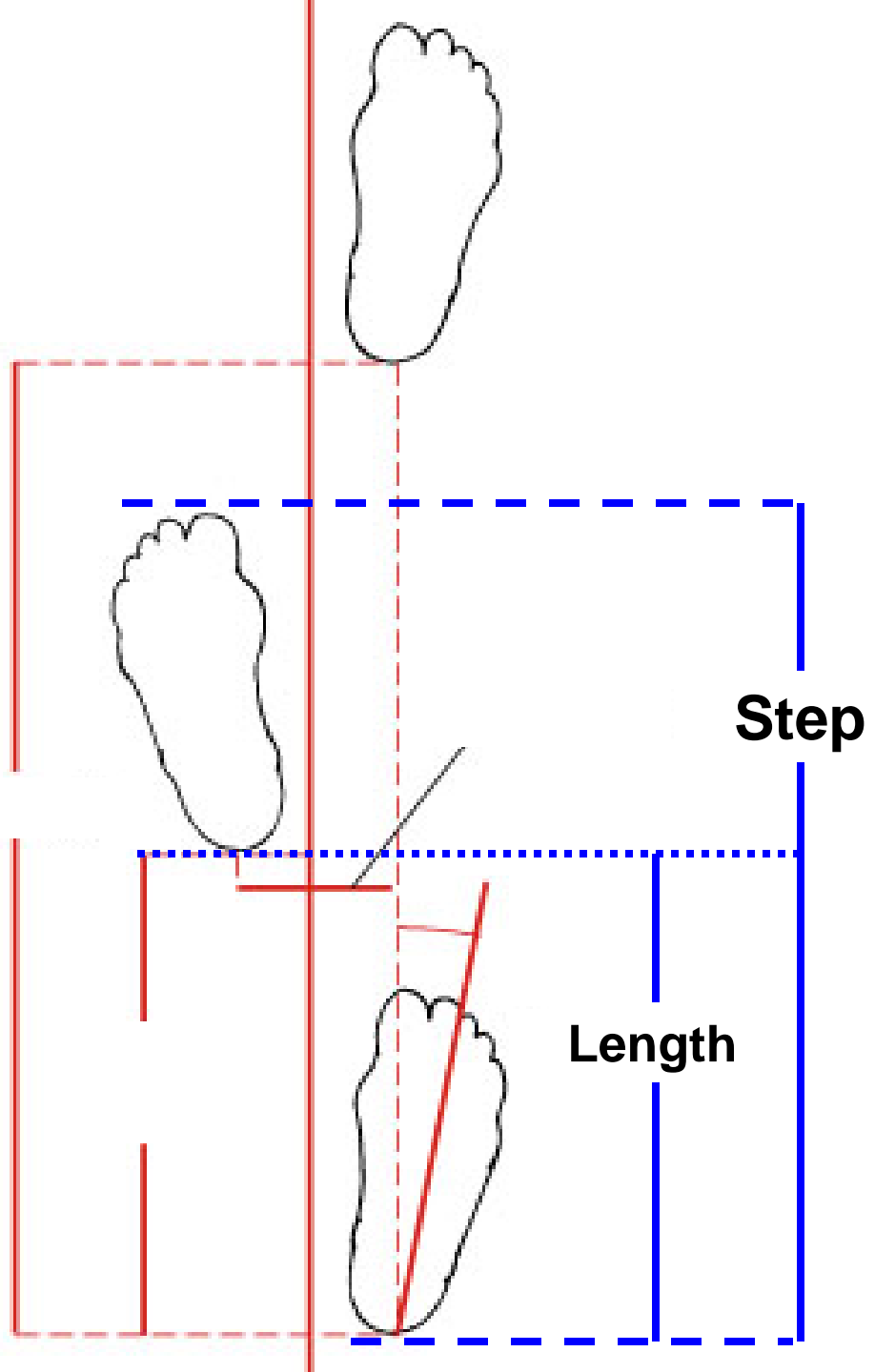


Displacement

Ψ **Step** – movement of 1 limb from HS to HS of opposite limb

Ψ **Step Length** - distance from HS of 1 foot to next HS of the other foot

Ψ Mean: 28" (0.70 m)



Displacement

Ψ **Step Width or Walking Base Width (BoS)** -

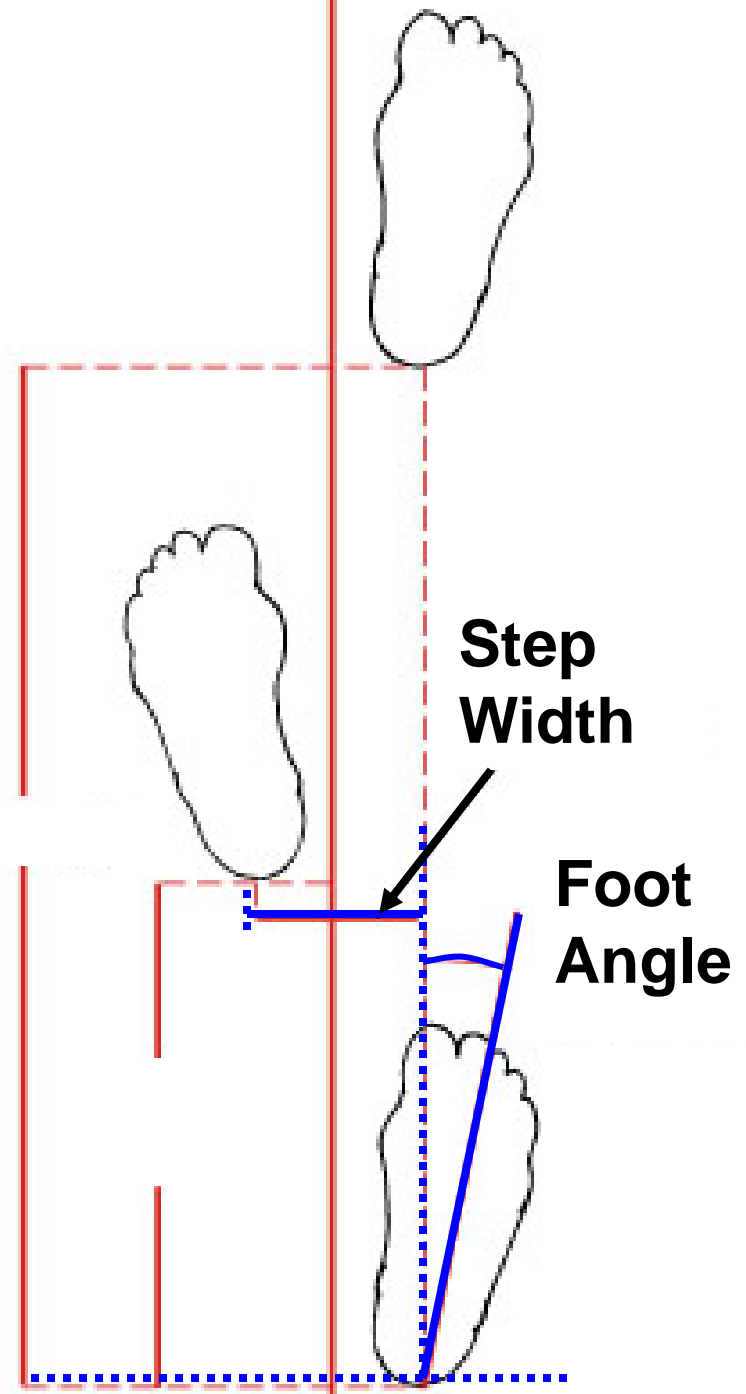
perpendicular distance between midpoint of heel on 1 foot to same point on other foot

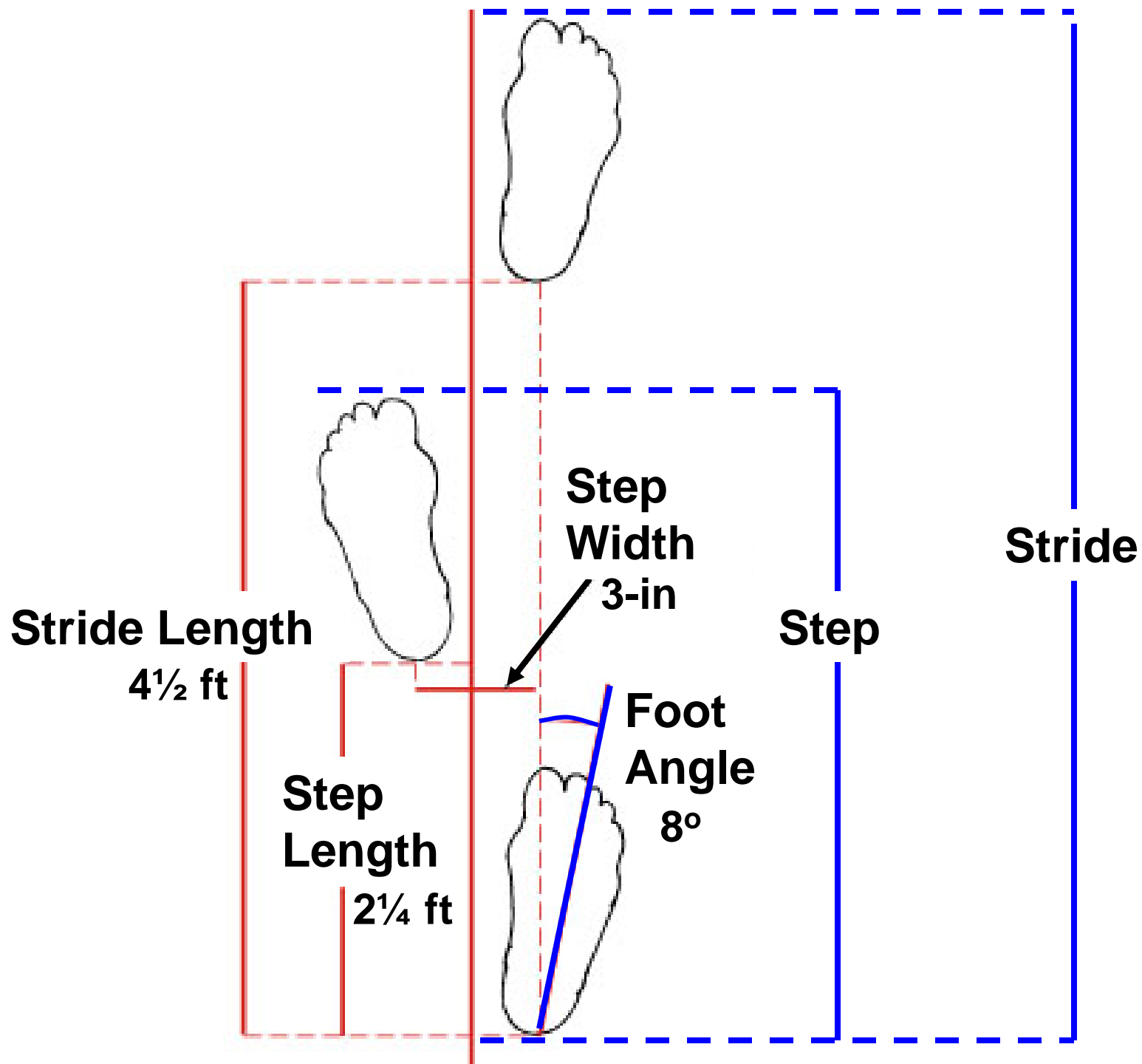
- Mean: 3" (8 cm)

Ψ **Foot Angle (Toe-out)** -

angle between long axis of foot & line of forward progression

- Mean: 8° out-toeing





Gait Parameters - Temporal

Stride Time - time from HS of 1 foot to HS of same foot

Walking Velocity – rate of forward linear motion

- Mean: 3 mph (1.3 m/s)
- Male 1.37; Female 1.28

Cadence – number of steps per unit time

- Mean: 112 steps/min
- Male 110; Female 118

Stance Time - time foot is on ground in a gait cycle

Swing Time - time foot is off ground in a gait cycle

Swing/Stance Ratio - ratio of swing to stance times

Double Support Time - time that 2 feet are in contact with the ground during a gait cycle

Single Support Time - time that 1 foot is in contact with the ground during a gait cycle



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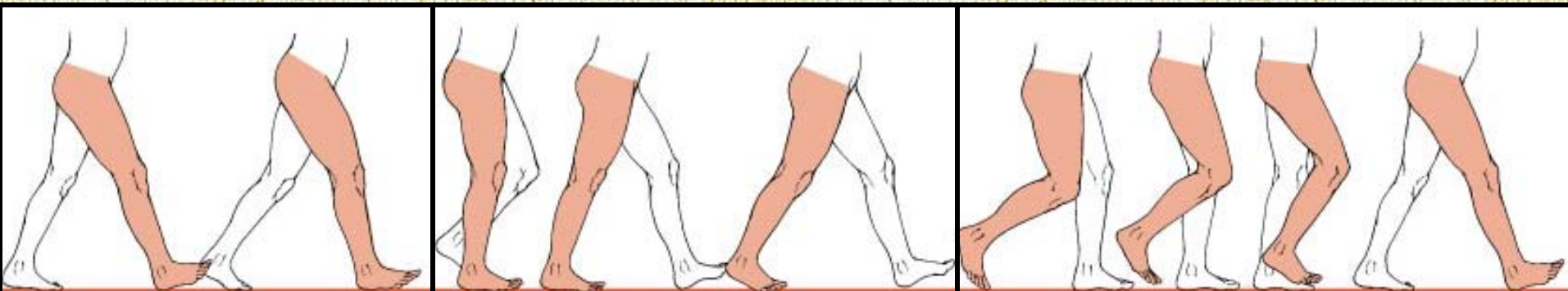
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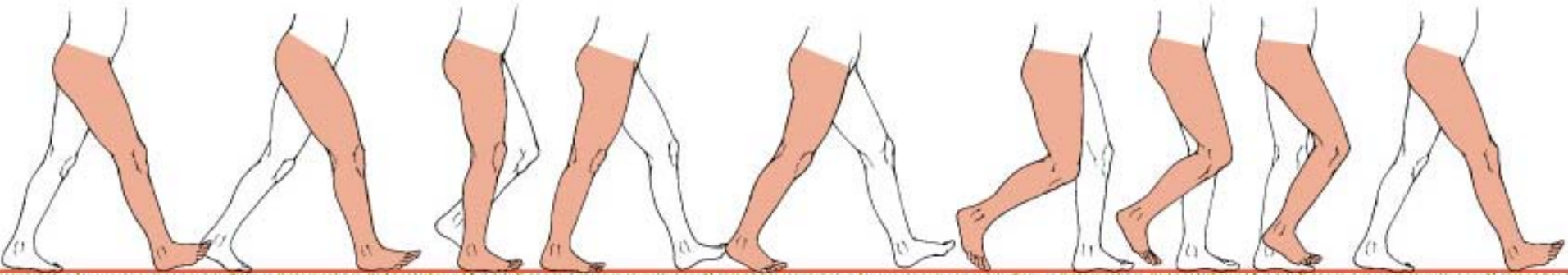
GAIT CYCLE – FUNCTIONAL TASKS



Gait Cycle - Functional Tasks

Observing gait from a **functional** standpoint

• 3 functional tasks



1. Weight Acceptance (WA)

2. Single Limb Support (SLS)

3. Swing Limb Advancement (SLA)

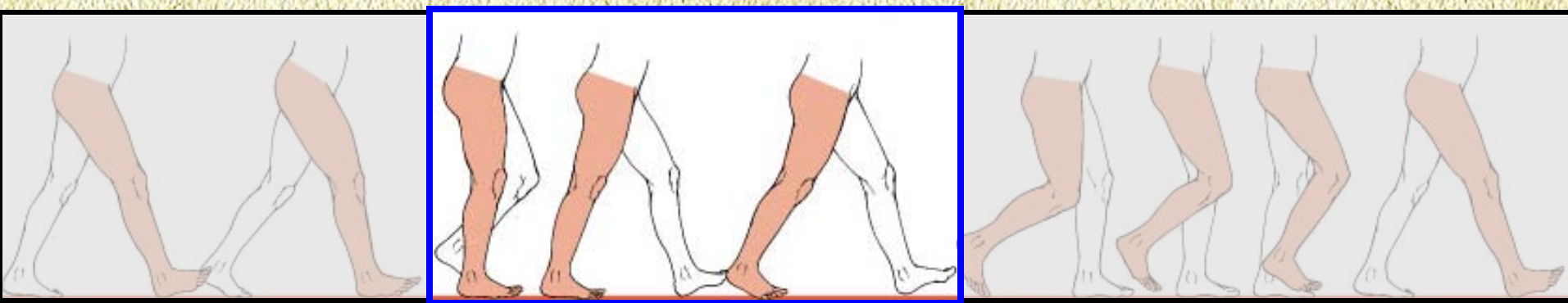
Gait Cycle - Functional Tasks



Weight Acceptance (WA)

- Ψ Includes HS & FF (loading of limb) in double support
- Ψ Absorption of ground impact force
- Ψ Body continues in forward path while maintaining stability

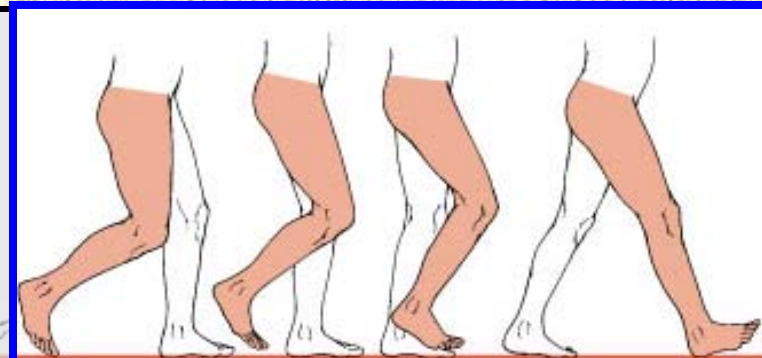
Gait Cycle - Functional Tasks



Single Limb Support (SLS)

- ❖ Includes MSt & HO; heel comes off ground
- ❖ Body progresses over single, stable, fully loaded limb
- ❖ Body weight transferred onto metatarsal heads

Gait Cycle - Functional Tasks



Swing Limb Advancement (SLA)

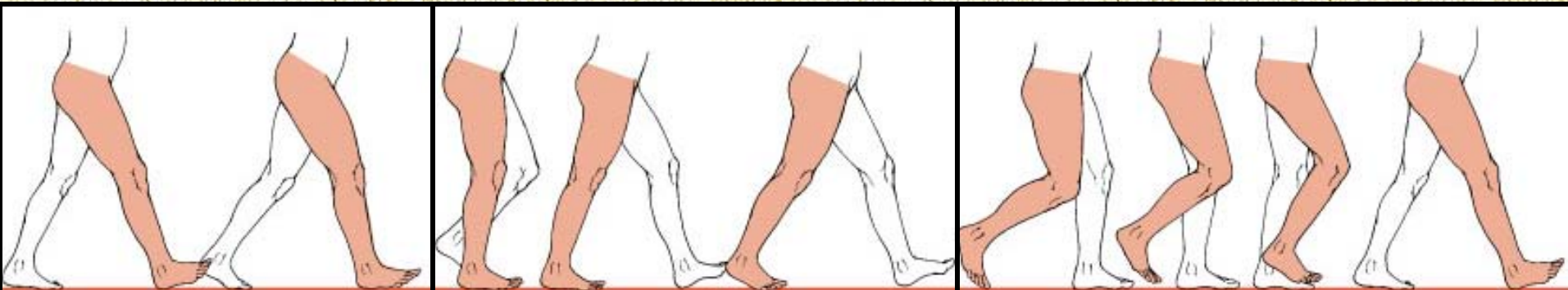
- Ψ Includes TO & all of Swing
- Ψ Limb is unloaded & foot comes off ground
- Ψ Limb is moved from behind the body to in front of the body, reaching out to take the next step





GAIT CYCLE – FUNCTIONAL TASKS

The Critical Events – What To Look For At The Ankle, Knee, & Hip



Critical Events

- Ψ Specific joint positions or motions that contribute to accomplishing **Functional Tasks**
- Ψ Each phase has 1 or more **Critical Event** at the Ankle, Knee, or Hip in the sagittal plane
 - Sagittal most important in contributing to gait & is primary focus of observational analysis
 - Yet secondary planes also contribute

Critical Events

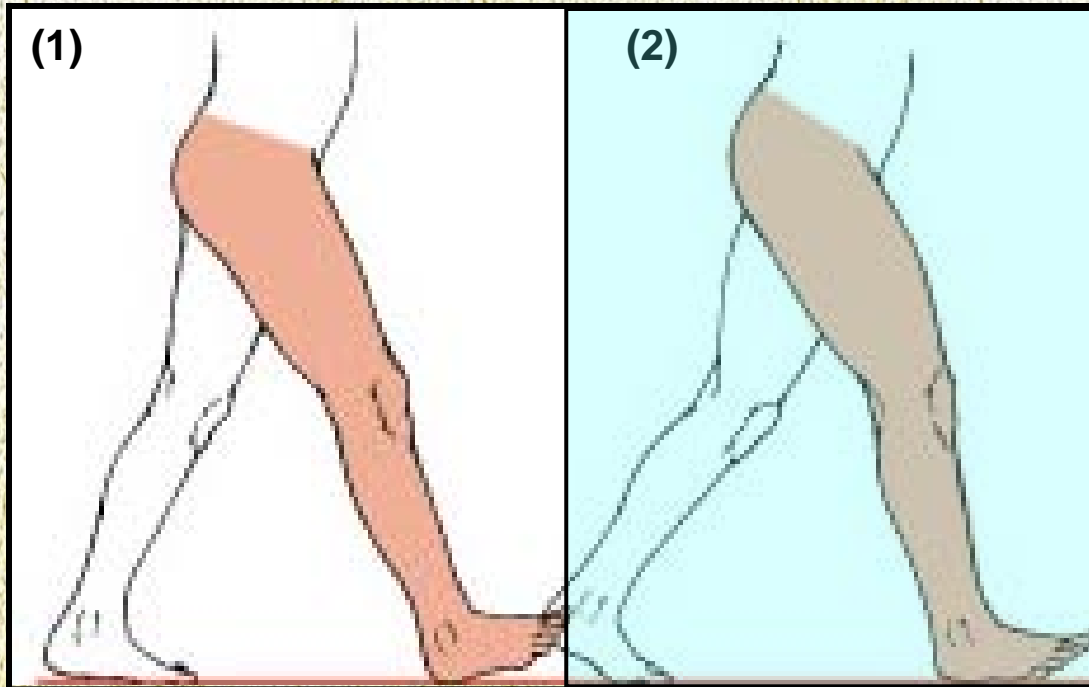
During each gait phase, the Ankle, Knee, & Hip are commonly described by:

1. **ROM** – what moved where
2. **Torque Demand (TD)**
 - Stability response to LoG position
3. **Muscle Action (MA)**
 - EMG: measured as On or Off
4. **Functional Significance (FS)**
 - What happens?
 - Reasons for ROM, TD, & MA?

Ankle - Weight Acceptance

Heel-Strike

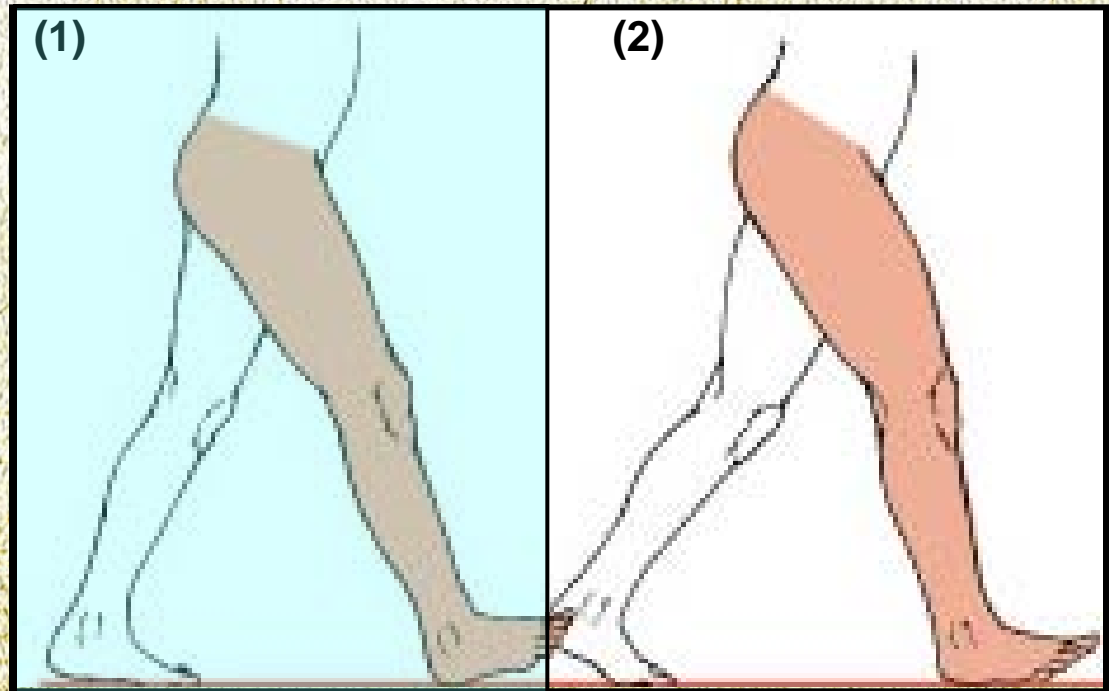
1. **ROM:** Neutral
4. **FS:** Foot correctly positioned for loading; heel-rocker



Ankle - Weight Acceptance

Loading Response

- 1. ROM:** 5° very rapid PF
- 4. FS:** Heel-rocker action created; Pretibials pull tibia forward creating forward momentum & flexes knee

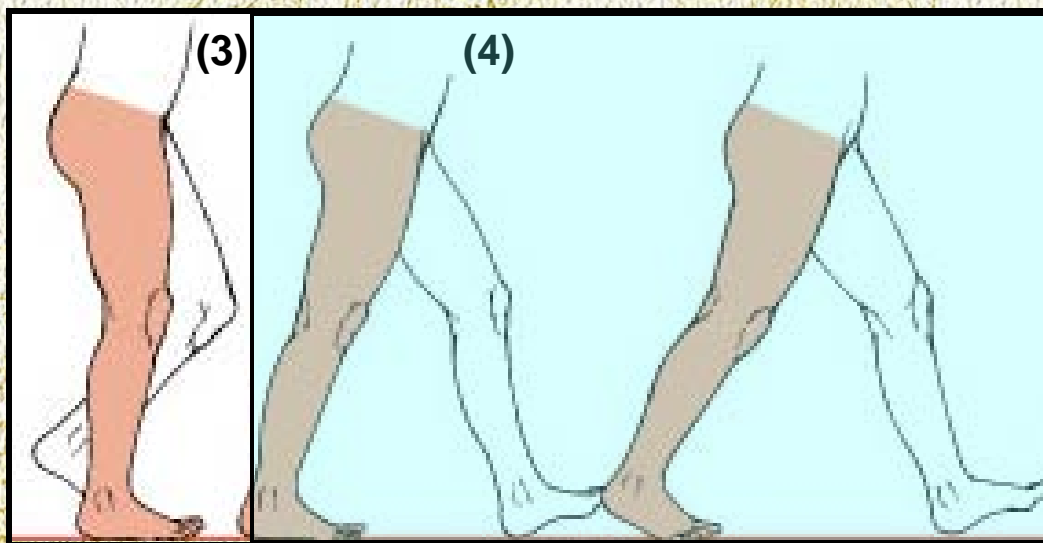


Ankle – Single Limb Support

Mid-Stance

1. ROM: DF to 5°

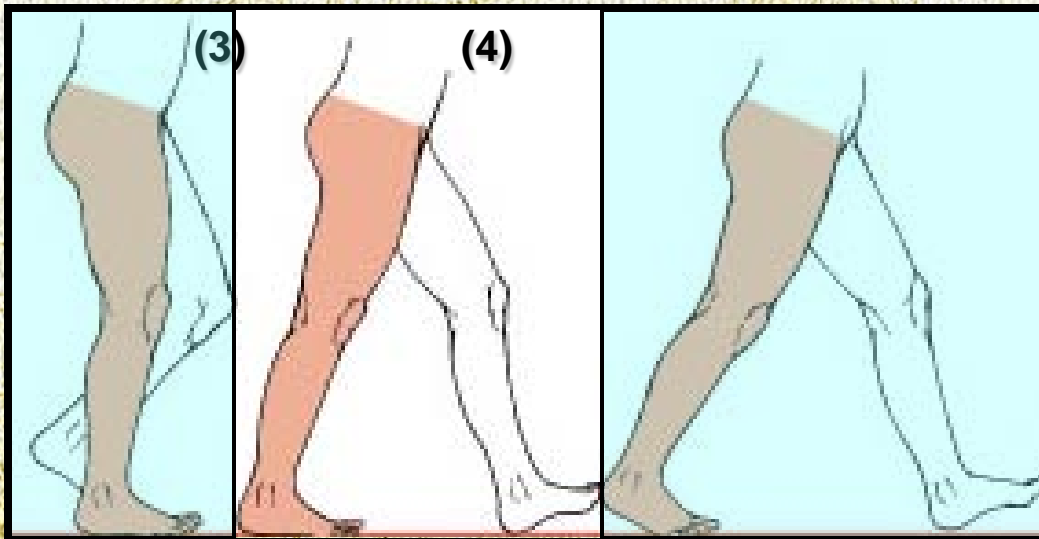
4. FS: Body progresses forward over stable foot & tibia; Calf creates knee stability by controlling tibial advancement; Forward momentum maintained while ankle moves into 5° DF = *Ankle Rocker*



Ankle – Single Limb Support

Heel-Off

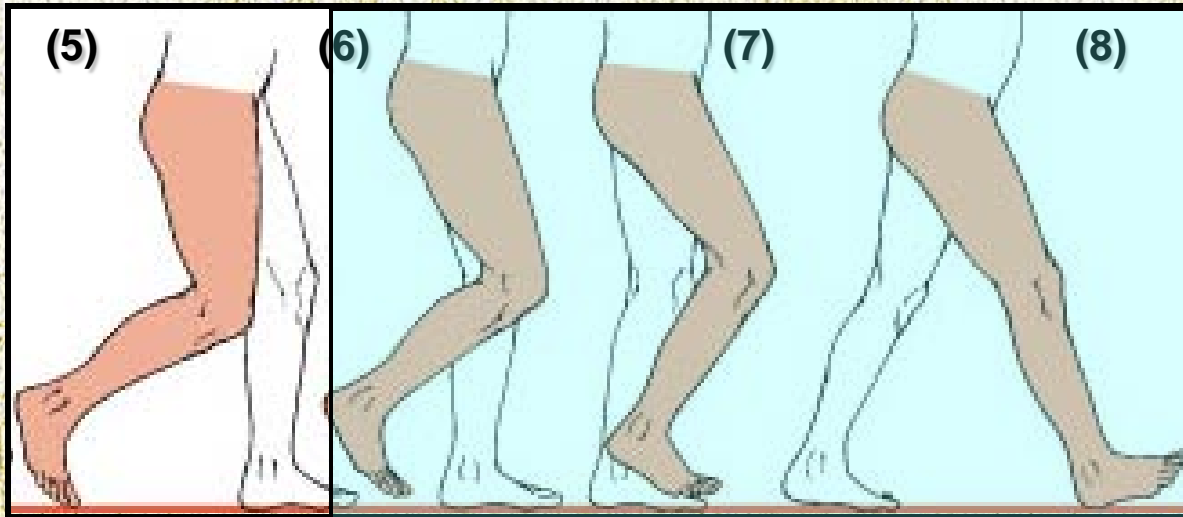
- 1. ROM:** DF to 10° ; MTP Hyperextension to 30°
- 4. FS:** Calf allows max forward progression - controls DF & allows heel rise = *Forefoot Rocker*, contralateral step length



Ankle – Swing Limb Advancement

Toe-Off

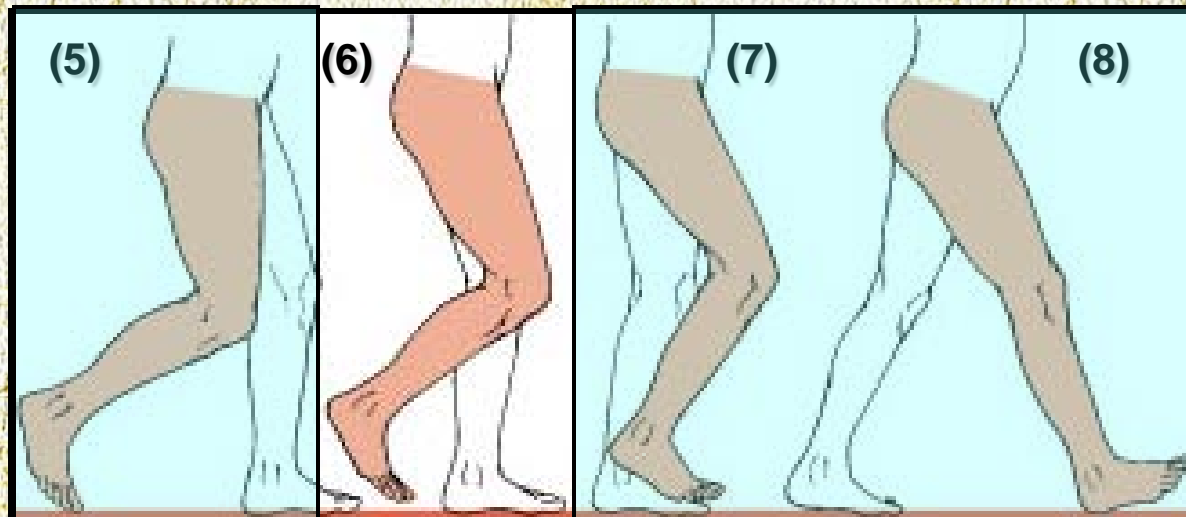
- 1. ROM:** Ankle into 15° PF; MTP into 60° hyperext
- 4. FS:** Forefoot remains on floor for balance assist; PF of partially unweighted foot assists with knee flexion & Swing Limb Advancement



Ankle – Swing Limb Advancement

Initial Swing

- 1. ROM: PF to 5°**
- 4. FS: begin DF to clear foot in next phase; DF to neutral not yet achieved**



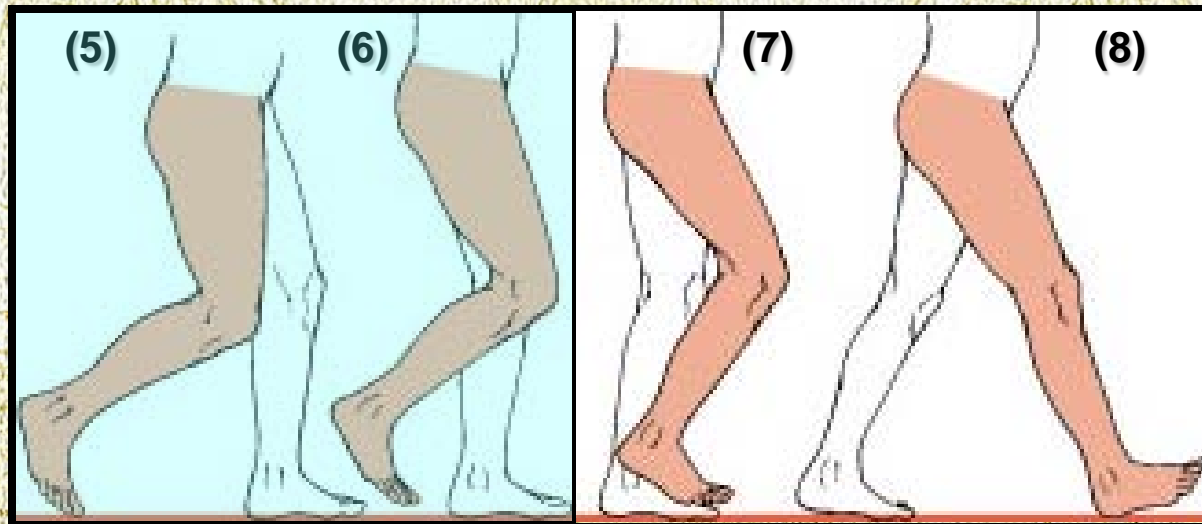
Ankle – Swing Limb Advancement

Mid-Swing

- 1. ROM:** DF to 0°
- 4. FS:** Foot clears ground by 1 cm

Terminal Swing

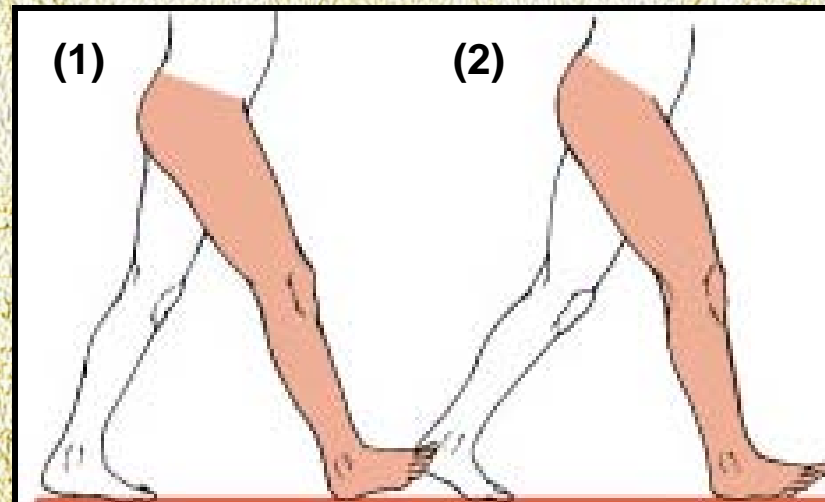
- 1. ROM:** Ankle remains neutral
- 4. FS:** Neutral position assures heel contact for HS



Subtalar - WA

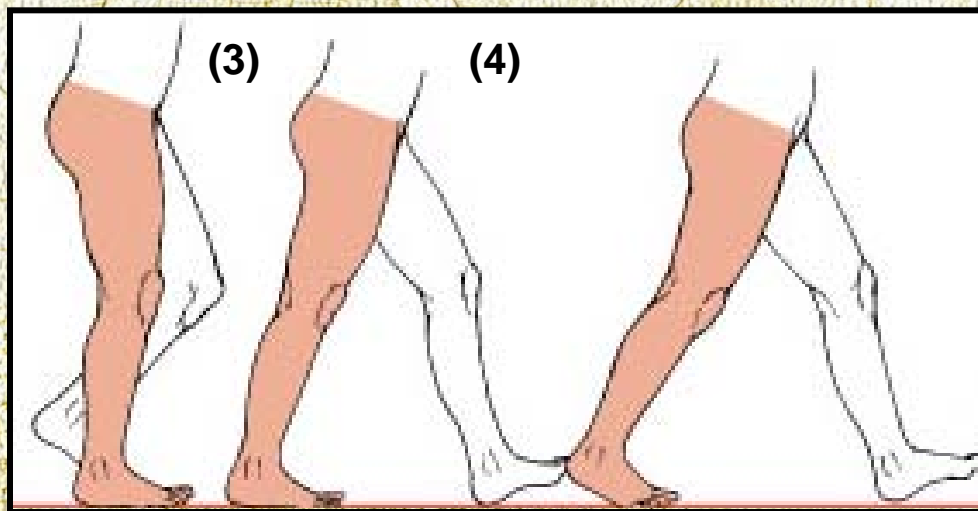
Heel Strike & Loading Response

1. **ROM:** Calcaneus Everts 5°;
Subtalar moves into pronation
4. **FS:** Subtalar joint Pronation *unlocks Midtarsal joint* & assists in shock absorption; Pronation induces Tibial Internal Rot, reduces rotatory stress on ankle joint



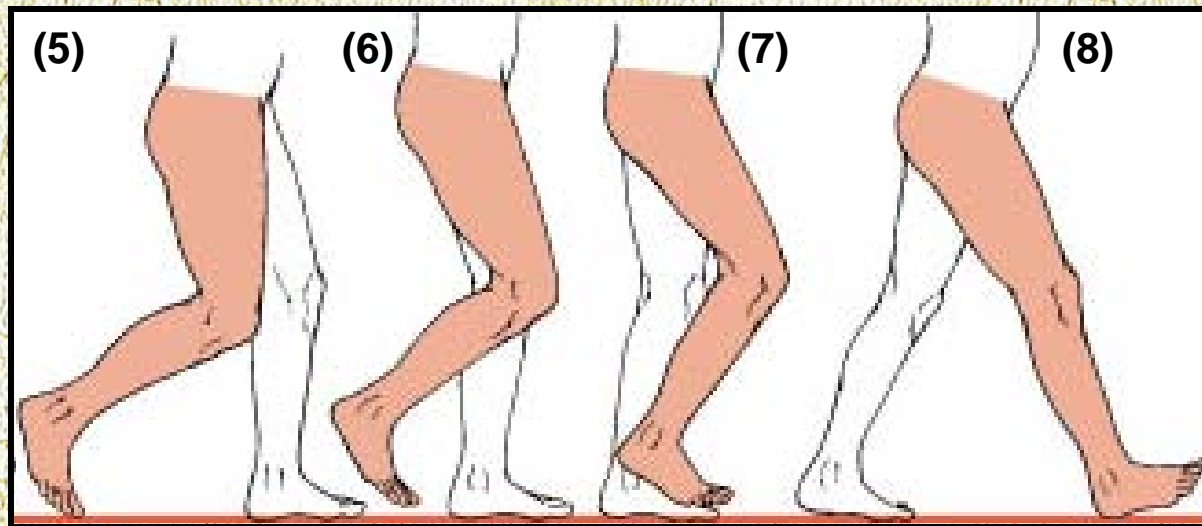
Subtalar – Single Limb Support

1. **ROM:** Progressive reduction of Eversion to $\approx 2^\circ$
4. **FS:** Tib Post & Soleus activity initially provide ecc control of EV, then con to move subtalar towards INV
 - Reduction in calcaneal EV \uparrow stability of midtarsal joints, creates rigid forefoot lever during late Stance
 - Promotes Forefoot Rocker
 - Peroneus Longus & Brevis provide lateral stability



Subtalar – Swing Limb Advancement

1. **ROM:** Subtalar joint achieves neutral position
4. **FS:** Foot clears ground; Ankle & Subtalar positioned for Heel-Strike



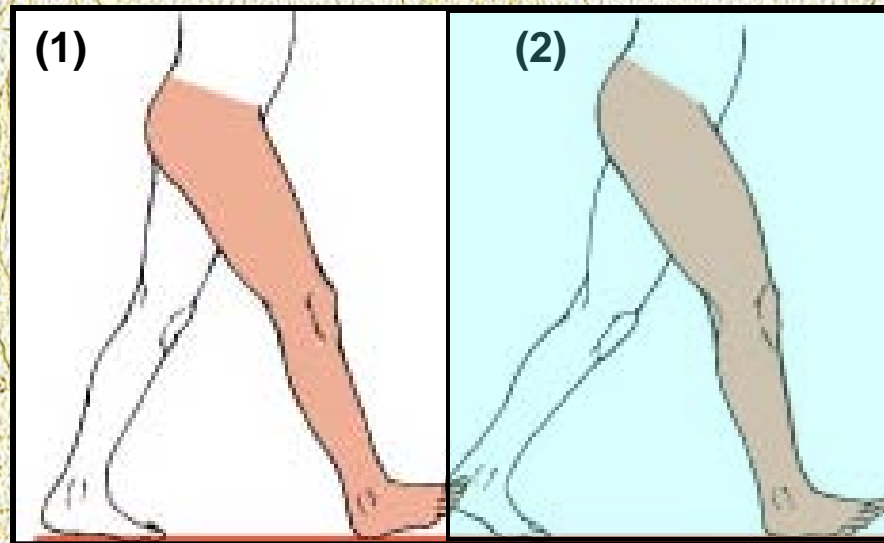
Ankle & Subtalar

Heel-strike.....	neutral	}	EV 5°, overall pronation
Loading Response...	PF 5°		
Mid-stance.....	DF to 5°	}	Reduce EV to about 2°
Heel-off.....	DF to 10°		
Toe-off.....	PF 15°	}	Overall neutral
Initial Swing.....	PF 5°		
Mid-swing.....	DF to 0°		
Terminal Swing.....	neutral		

Knee - Weight Acceptance

Initial Contact

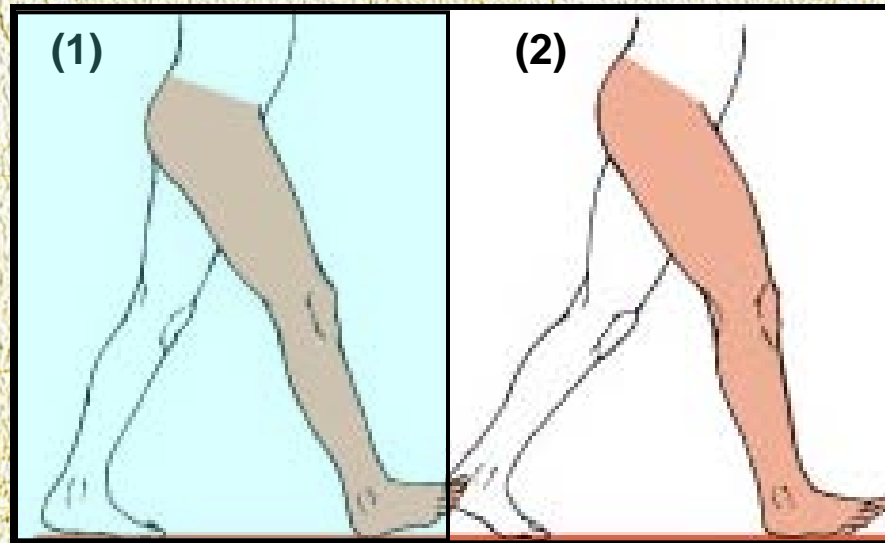
- 1. ROM:** Appears neutral, may be slightly flexed to 5°
- 4. FS:** At Heel-Strike, Extension torque stabilizes Knee



Knee - Weight Acceptance

Loading Response

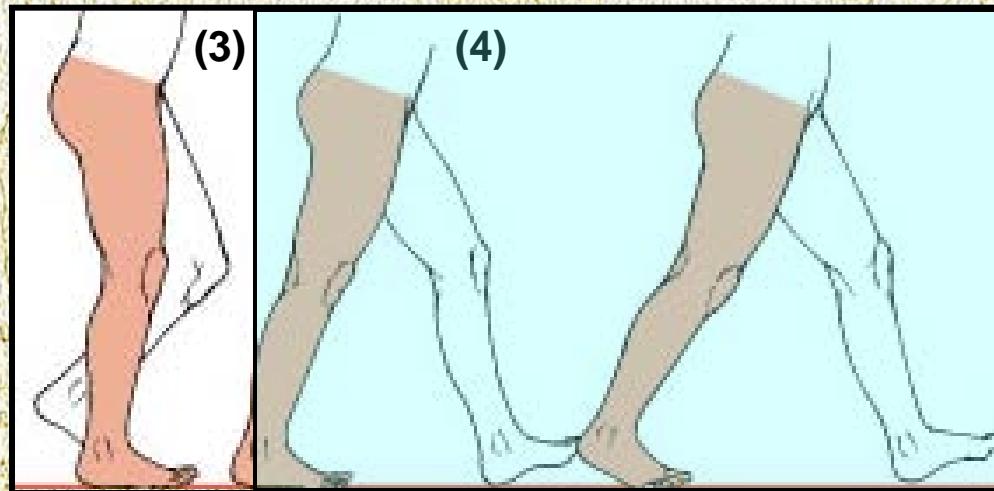
- 1. ROM:** Knee flexes to 15°
- 4. FS:** Shock absorbed & limb stability maintained while forward progression continues



Knee – Single Limb Support

Mid-Stance

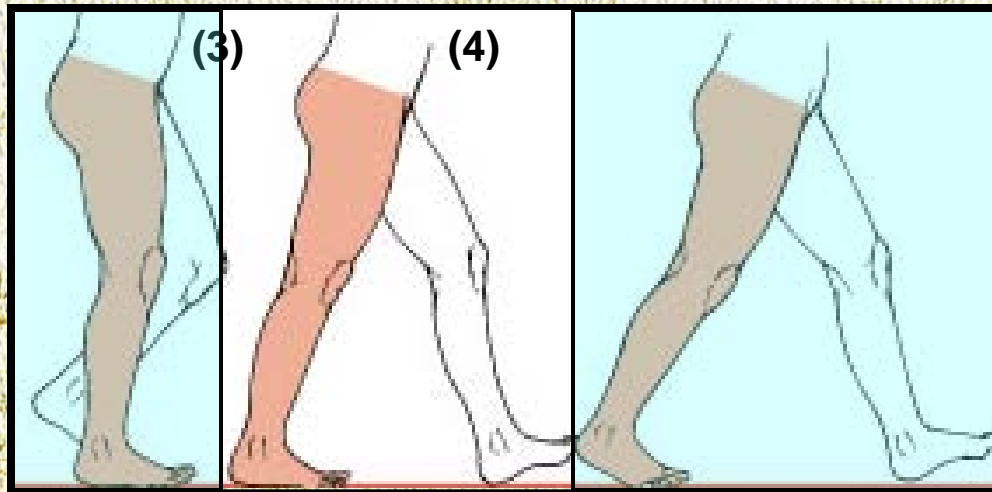
- 1. ROM:** Extends to $\approx 5^\circ$ Flexion; appears neutral
- 4. FS:** Knee stability maintained by Knee Extension torque & calf activity



Knee – Single Limb Support

Heel-Off

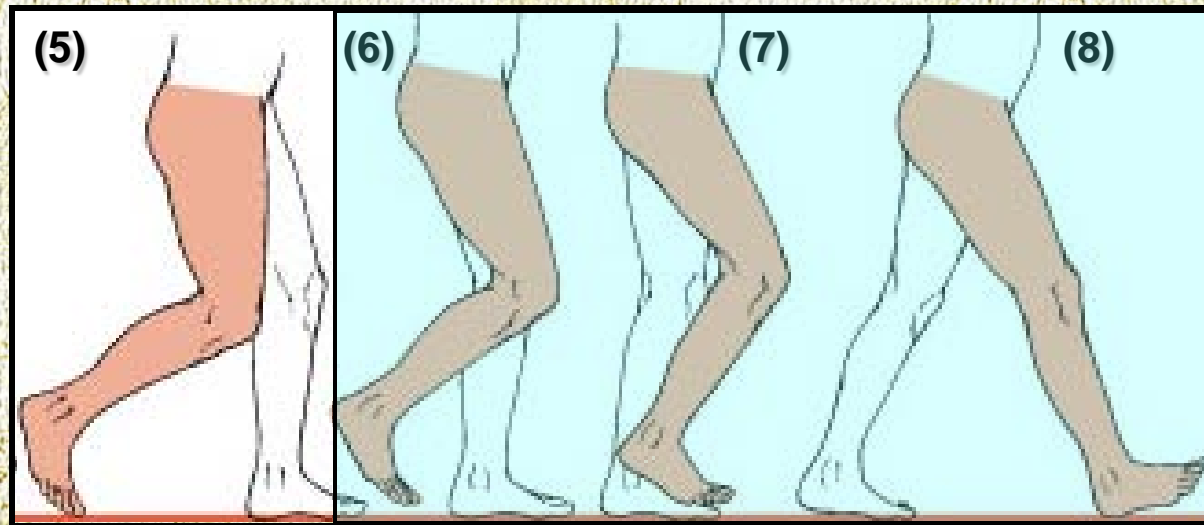
- 1. ROM:** Appears unchanged from Midstance
- 4. FS:** Joint stability maintained during forward progression



Knee – Swing Limb Advancement

Toe-Off

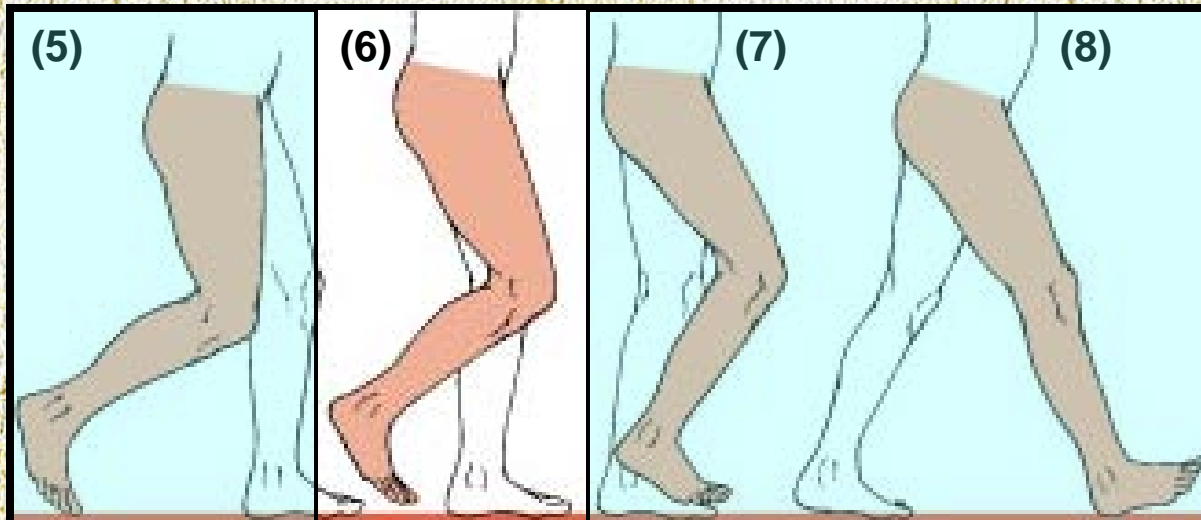
1. **ROM:** Rapidly Flexes to 40°
4. **FS:** Pre-swing KF adds to KF needed for limb clearance



Knee – Swing Limb Advancement

Initial Swing

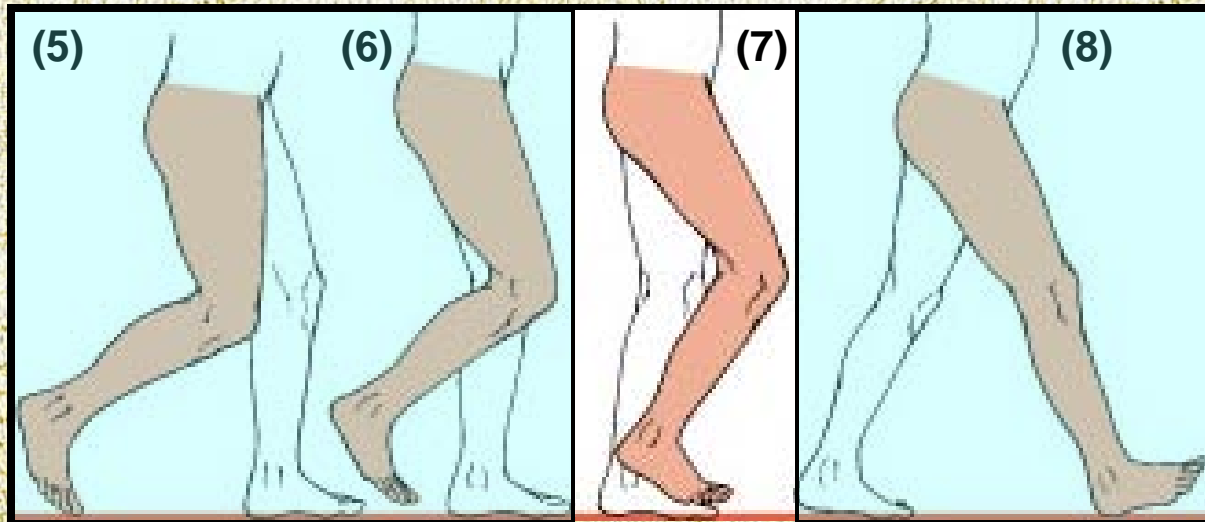
- 1. ROM:** Further rapid knee flexion to 60°
- 4. FS:** Foot clears ground as Thigh begins to advance



Knee – Swing Limb Advancement

Mid-Swing

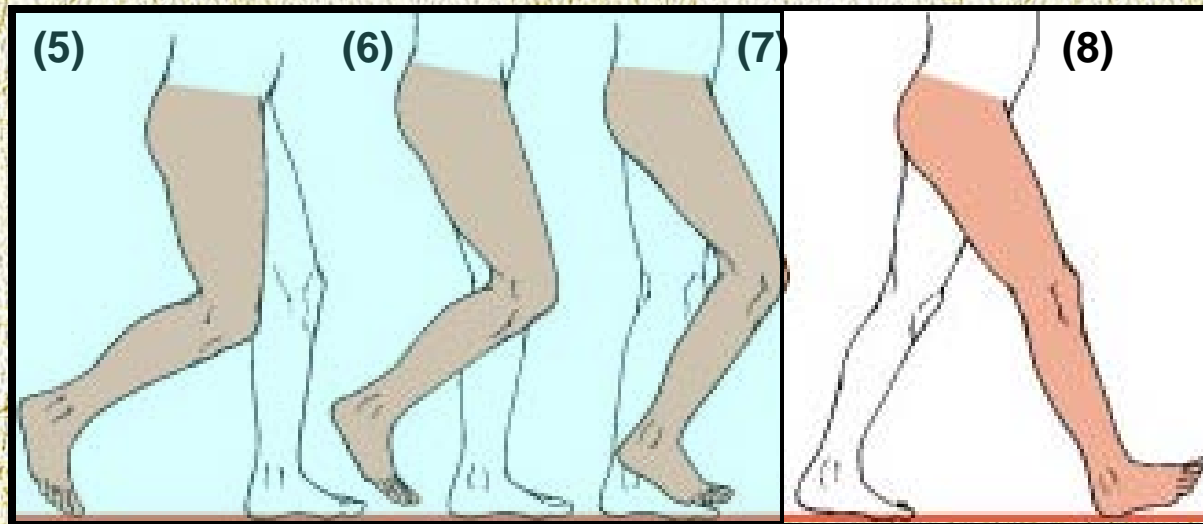
- 1. ROM:** Knee rapidly Extends to 25°; Tibia achieves vertical position
- 4. FS:** Knee Ext necessary as step length begins



Knee – Swing Limb Advancement

Terminal Swing

- 1. ROM:** Extends to neutral, may move into 5° Flex
- 4. FS:** Step length optimized by leg reaching out



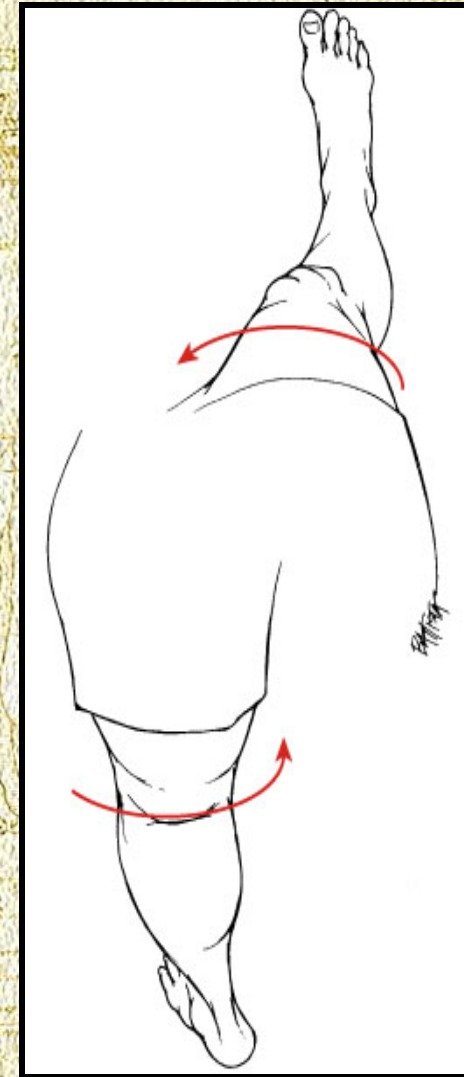
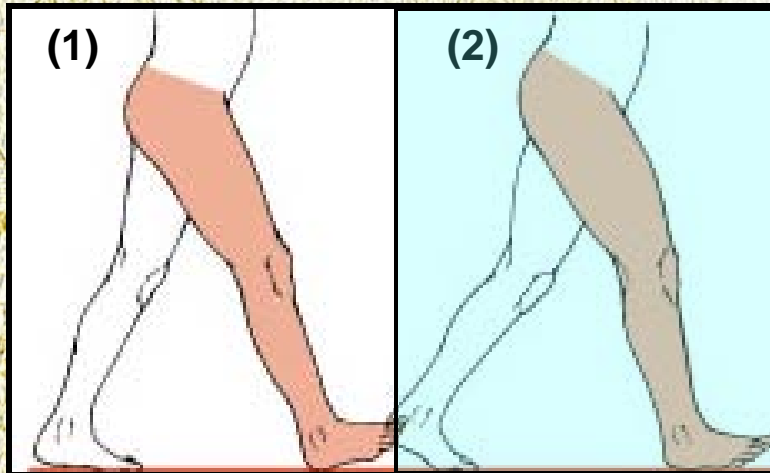
Knee

Heel-strike.....	neutral or KF 5°
Loading Response...	KF 15°
Mid-stance.....	KE to 5°, appears neutral
Heel-off.....	no change
Toe-off.....	rapid KF to 40°
Initial Swing.....	KF to 60°
Mid-swing.....	rapid KE to 25°
Terminal Swing.....	neutral or KF 5°

Hip & Pelvis - Weight Acceptance

Heel-Strike

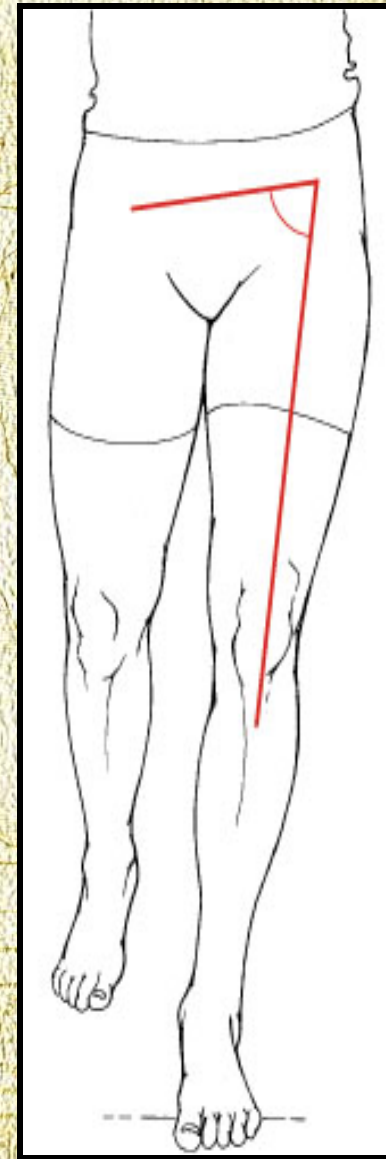
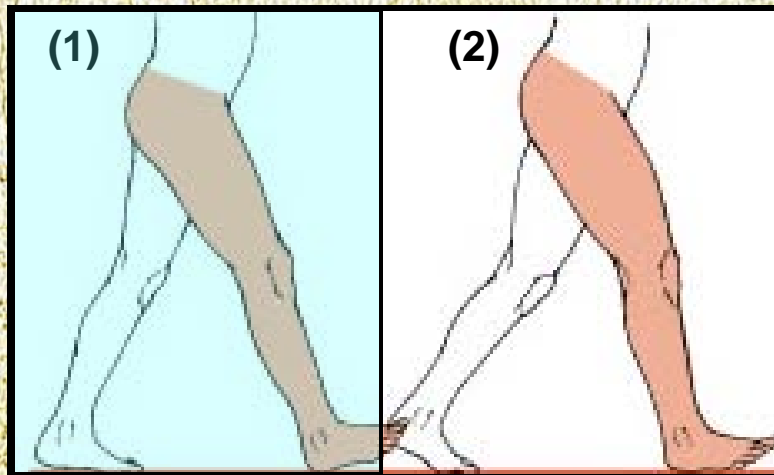
- 1. ROM:** 20° of Hip Flexion; pelvis is in 5° of forward rotation
- 4. FS:** Hip & Pelvis in position of forward reach



Hip & Pelvis - Weight Acceptance

Loading Response

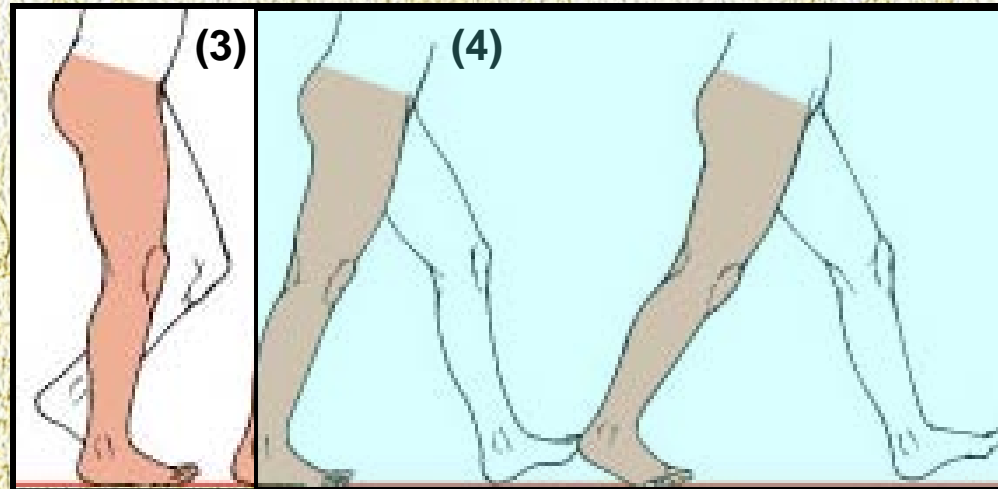
- 1. ROM:** Hip remains in 20° of Flexion; Pelvis remains in 5° forward rotation
- 4. FS:** Hip joint stable during shock absorption; Trunk Flexion prevented, Thigh stabilized; Pelvis stable in frontal plane



Hip & Pelvis – Single Limb Support

Mid-Stance

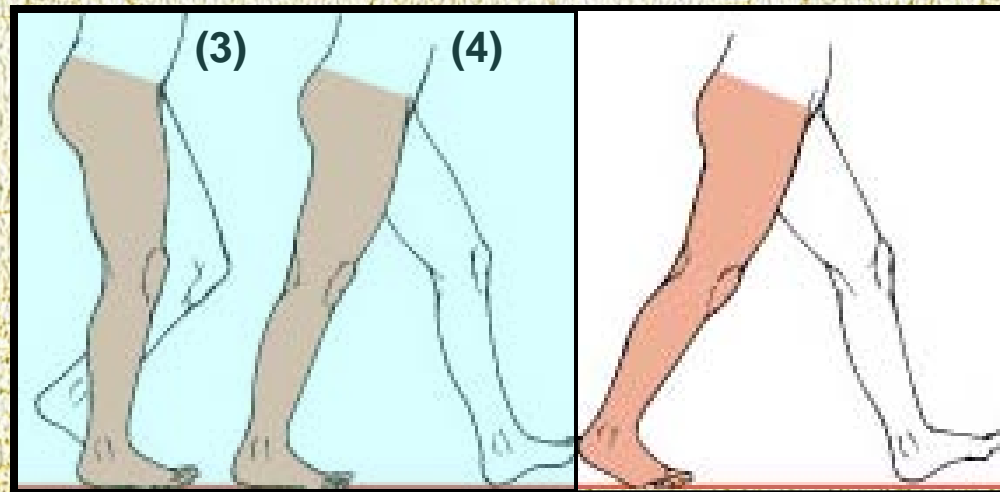
1. **ROM:** Ext to neutral; Rotates backwards to neutral
4. **FS:** Stable position achieved in sagittal plane without Hip Extensors; Pelvis stabilized to prevent Hip drop



Hip & Pelvis – Single Limb Support

Terminal Stance

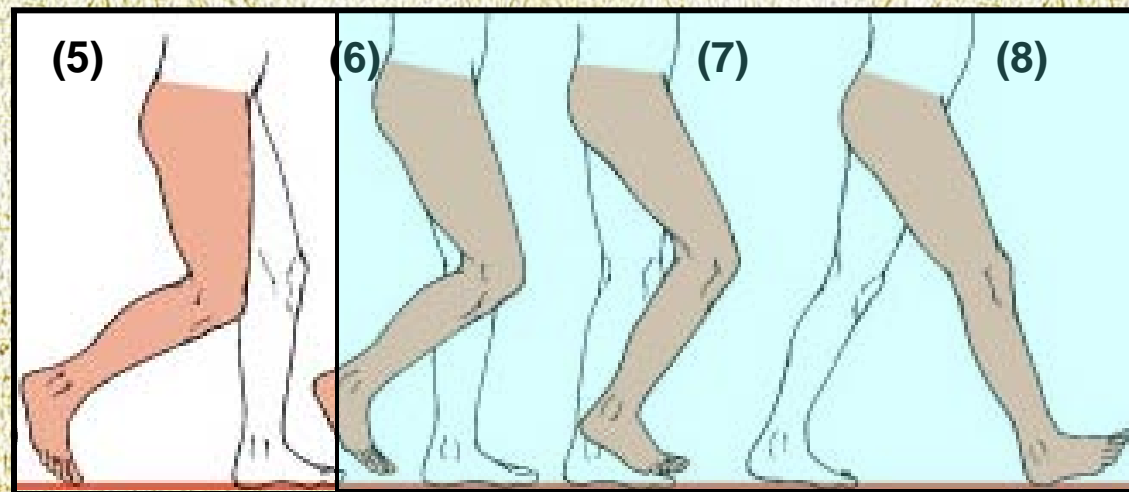
- 1. ROM:** Hip Extends to trailing position of 20° Hyperextension; Pelvis rotates 5° backwards
- 4. FS:** Body advances past foot to maximize step length, limb still stable; Pelvic Rot makes gait pattern look smooth



Hip, Pelvis – Swing Limb Advancement

Toe-Off

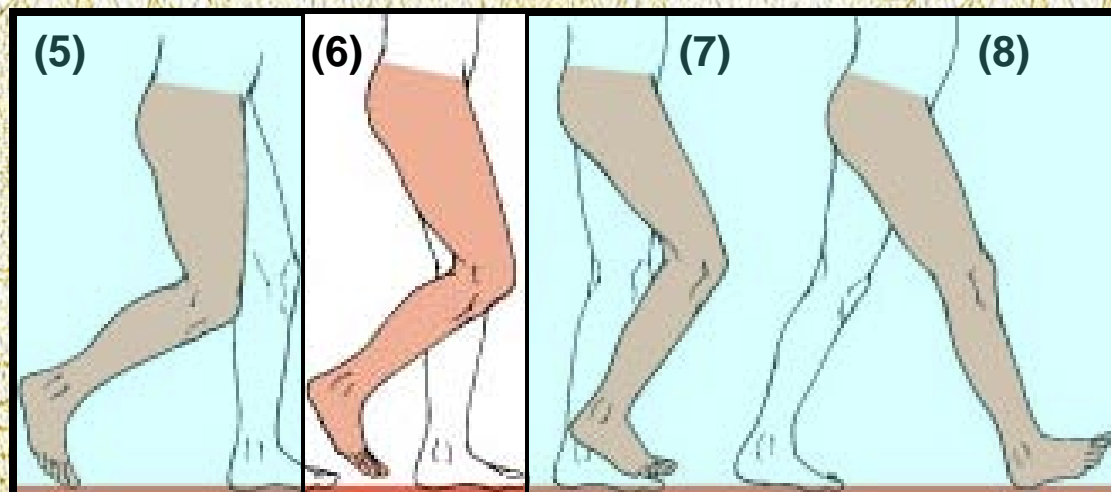
- 1. ROM:** Thigh falls forward; appears vertical, but in slight Hyperextension (10°); Pelvis remains in 5° backward rot
- 4. FS:** Limb advancement begins; Hip Flex adds to Knee Flex



Hip, Pelvis – Swing Limb Advancement

Initial Swing

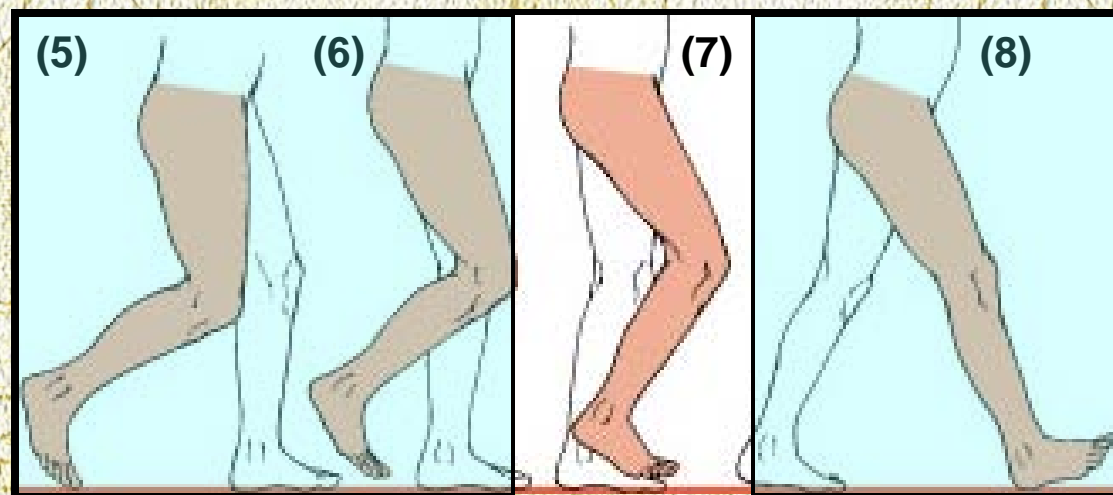
- 1. ROM:** 15° of Hip Flexion; Pelvis remains in 5° backward rot
- 4. FS:** Limb advancement continues



Hip, Pelvis – Swing Limb Advancement

Mid-Swing

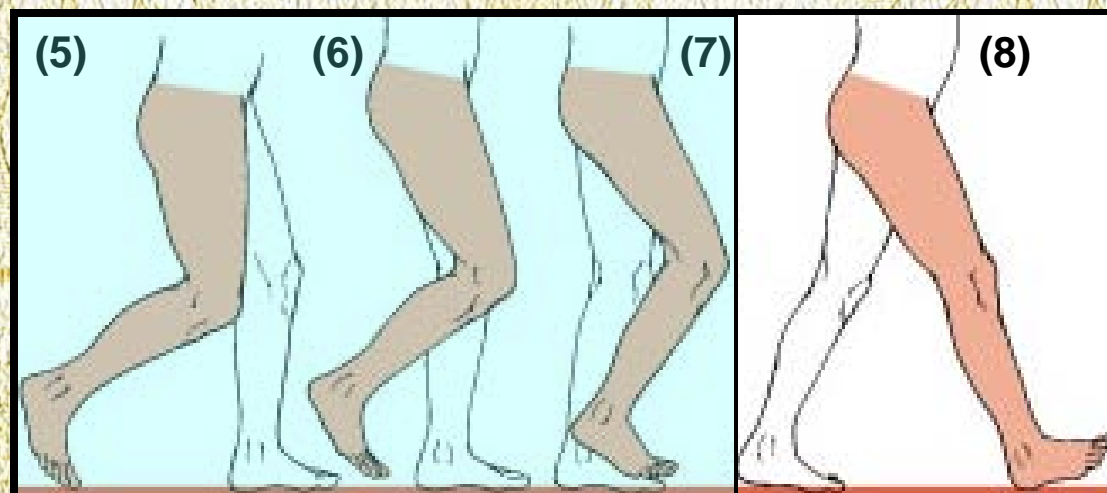
- 1. ROM:** 25° Hip Flexion; Pelvis in neutral rotation
- 4. FS:** Thigh advancement slows; momentum created by swinging limb helps carry body past stance limb



Hip, Pelvis – Swing Limb Advancement

Terminal Swing

- 1. ROM:** Thigh to 20° of Flex; Pelvis 5° forward rot
- 4. FS:** Limb positioned for heel-1st ground contact; forward rot of pelvis contributes to step length



Hip & Pelvis

Heel-strike.....	HF 20°; Fwd Rot 5°
Loading Response...	no change; no change
Mid-stance.....	neutral HE & Bwd Rot
Heel-off.....	HE _{hyp} 20°; Bwd Rot 5°
Toe-off.....	HE _{hyp} 10°; no change
Initial Swing.....	HF to 15°; no change
Mid-swing.....	HF to 25°; pelvis neutral
Terminal Swing.....	HF 20°; Fwd Rot 5°

Gait Summary - Weight Acceptance

	Hip		Knee		Ankle		Critical Event	Functional Significance
	ROM	MA	ROM	MA	ROM	MA		
HS	20° Flex	ext's	5° Flex	quads	0°	pre-tibs	<ul style="list-style-type: none"> • Heel first contact 	<ul style="list-style-type: none"> • Forward progression • Stability • Shock absorption
LR	20° Flex	ext's & abd's	15° Flex	quads	5° PF	pre-tibs	<ul style="list-style-type: none"> • Hip stability • Controlled knee flexion & PF 	

Gait Summary- Single Limb Support

	Hip		Knee		Ankle		Critical Event	Functional Significance
	ROM	MA	ROM	MA	ROM	MA		
MSt	0°	abd's	5° Flex	Initial quads	5° DF	Calf	<ul style="list-style-type: none"> Controlled tibial advancement 	<ul style="list-style-type: none"> Stability Forward progression
HO	20° hyper-ext	None	5° Flex	None	10° DF	Calf	<ul style="list-style-type: none"> Controlled DF with heel rise Trailing limb. 	

Gait Summary - Swing Limb Advancement

	Hip		Knee		Ankle		Critical Event	Functional Significance
	ROM	MA	ROM	MA	ROM	MA		
PSw	10° hyper ext	add's	40° Flex	None	15° PF	None	<ul style="list-style-type: none"> • Passive knee flex to 40° • PF 	<ul style="list-style-type: none"> • Foot clearance • Limb advancement
ISw	15° Flex	flex's	60° Flex	flex's	5° PF	pre-tibs	<ul style="list-style-type: none"> • Hip flex to 15° • Knee flex to 60° 	

Gait Summary - Swing Limb Advancement

	Hip		Knee		Ankle		Critical Event	Functional Significance
	ROM	MA	ROM	MA	ROM	MA		
MSw	25° Flex	flex's initial, then hams	25° Flex	flex's	0°	pre-tibs	<ul style="list-style-type: none"> • Further hip flex to 25° • DF to 0° 	<ul style="list-style-type: none"> • Foot clearance • Limb advancement
TSw	20° Flex	hams	5° Flex	quads	0°	pre-tibs	<ul style="list-style-type: none"> • Knee ext to neutral (possibly 5° flex) 	

Systematically Observe Gait

Record Observed Deviations

Determine Significant Deviations That Interfere with Functional Tasks

Consider Possible Causes

- Impaired Strength
 - ROM Deficits
- Sensory Deficits
 - Pain

Determine Likely Cause

Provide Appropriate Interventions

Re-Assess Gait

Problem Solving for Gait Analysis