

# A Qualitative Description of Normal Gait

By James R. Gage, M.D.

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## Requirements for Gait Include:

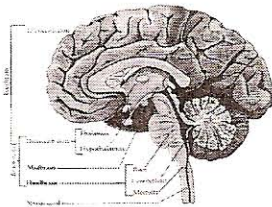
- Control System
- Energy Source
- Skeletal Levers
- Motors (Muscles)

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## The Control System is Responsible for:

- Initiation and control of movement
- Balance and stability throughout the activity

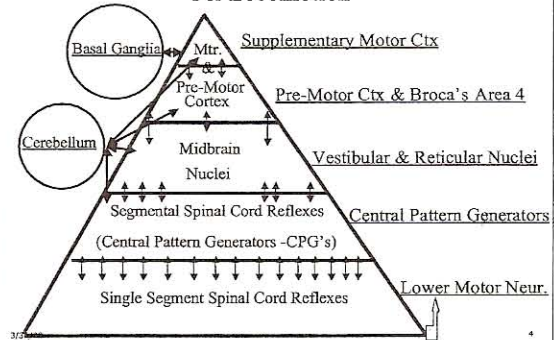


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## The Control Pyramid

For Locomotion

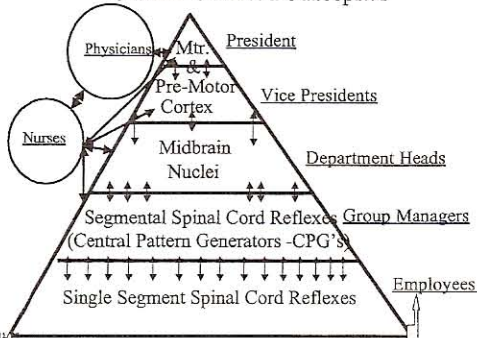


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## The Control Pyramid

Gillette Children's Hospital



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## Energy Source

- Speed and distance traveled are dependent upon
  - Rate of energy production and transport to muscles ( $VO_2$  max)
  - Extent of energy conservation

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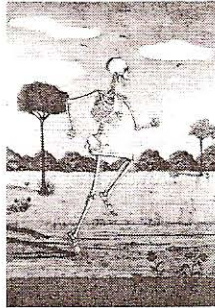
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## Skeletal Levers

- Muscles forces and ground reaction forces provide the power for movement
- Skeletal levers provide the means by which these forces produce movement
  - i.e., *Bones are the moment arms upon which the forces act*



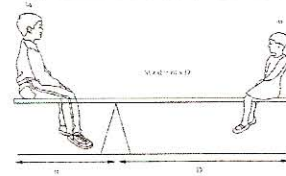
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## What Defines a Moment?

- The product of a force times the distance of the force from the center of an axis of rotation.
- An unopposed moment will produce an angular acceleration about its axis. The unit is Newton-meters.

### Moments to Remember

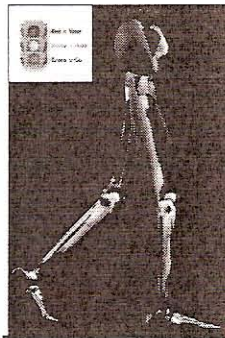


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## Muscles

- Function determines form and fiber type
  - Power = force x velocity
    - Relates primarily to cross sectional area & secondarily to fiber type
      - ❖ ~30 N / cm<sup>2</sup> of cross sectional area
      - ❖ Fiber types:
        - I - slow twitch, aerobic
        - II - fast twitch, aerobic
        - III - fast twitch, anaerobic



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## Modes of Muscle Action

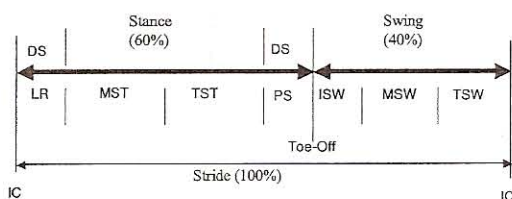
- **Concentric** (shortening under tension)
  - All accelerators work in this mode
- **Eccentric** (lengthening under tension)
  - Decelerators and shock absorbers work in this mode
- **Isometric** (tension, without change in length)
  - Stabilizers work in this mode



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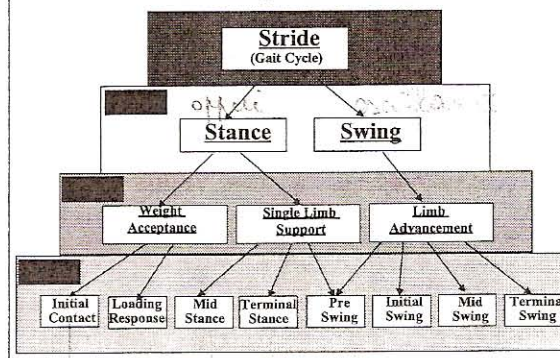
## THE GAIT CYCLE: Walking



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## Divisions of the Gait Cycle





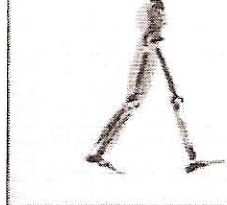
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## Prerequisites of Normal Gait

In order of priority:

1. Stability in stance
2. Clearance in swing
3. Pre-position of the foot in terminal swing
4. An adequate step-length
5. Energy conservation



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## Stability in Stance Requires:

- The stance foot to be stable on the floor
- The major lower extremity joints function to:
  - Allow advancement of the limb in swing
  - Maintain balance
  - Provide propulsion
  - Insure appropriate position of the structures above
    - Center of mass (com) remains within the base of support while standing, and moves forward from one base of support to the next while walking
- Trunk stability
- Adequate body balance

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## Clearance in Swing Requires:

- Stability of the stance foot
- Appropriate position and power of the ankle, knee and hip on the stance side
- Adequate ankle dorsiflexion, knee flexion and hip flexion on the swing side
- Adequate body balance

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## Pre-position of the Foot in TSw Requires:

- Stance side stability, power, and proper position
- Swing side
  - Adequate ankle dorsiflexion
  - Balance between inverters and everters of the foot
  - Appropriate knee position
  - Appropriate foot position
- Adequate body balance

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## An Adequate Step-length Requires:

- A stable and properly positioned stance side
- Neutral dorsiflexion, inversion and eversion
- Adequate hip flexion
- Adequate body balance
- Relatively complete knee extension

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## Energy Conservation Requires:

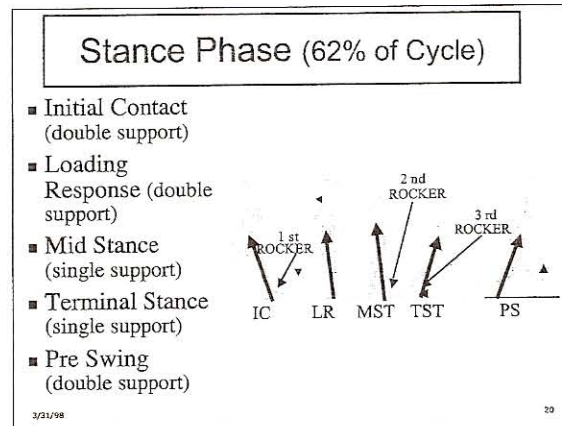
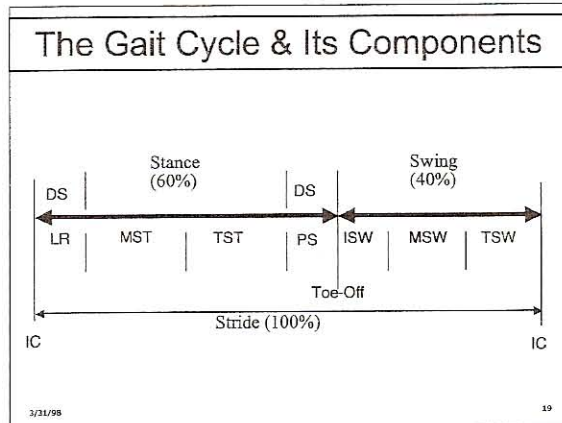
- The use of several biomechanical mechanisms.
  - Muscles tend to *lengthen* during gait rather than shorten.
  - "Stretch energy" is returned, since in normal gait muscles tend to be "pre-stretched before they fire concentrically."
  - Bi-articular muscles usually serve as energy transfer straps.
- Joint stability is provided by the ground reaction force (GRF) in conjunction with ligaments when possible.
- Center of mass excursion is minimized in all planes.

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### Initial Contact (Double Support)

- An instantaneous event which initiates the gait cycle

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### Loading Response (Double Support)

- Its purpose is shock absorption
- Utilizes eccentric muscle action at the ankle and knee but not the hip

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### Midstance (Single Support)

- Its purpose is to provide extrinsic stability of the knee and so relieve the quadriceps and reduce the work of walking.
  - > The Plantar-flexion / Knee-extension Couple

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### Terminal Stance (Single Support)

- Its purpose is acceleration
- Combined concentric action of the gastrocnemius and soleus generates nearly half of the total propulsive force for walking

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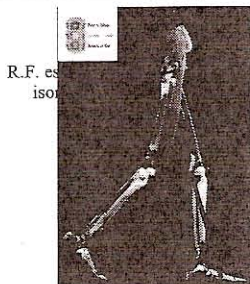
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*Limb: 1*

## Pre-swing (Double Support)

- Its purpose is to transfer weight to the opposite limb and to unlock the stance limb for swing.
- The iliopsoas and the rectus femoris have most of their activity in this phase of gait.

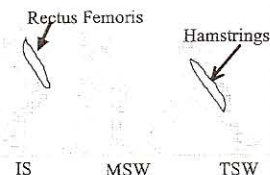


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## Swing Phase (38% of cycle)

- Initial Swing
- Mid Swing
- Terminal Swing



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## The Lower Extremity Functions As a Compound Pendulum

- The hip, knee, and ankle must flex sufficiently to allow adequate clearance
- The duration of swing varies in proportion to cadence, so a mechanism is needed to allow this
- Muscles need to provide adequate power to carry the limb through swing
- Energy transfers between body segments are necessary in order to minimize the work of walking.

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## The Purpose of Swing is to:

- Provide foot clearance
- Allow variation in cadence
- Conserve energy
- Advance the limb



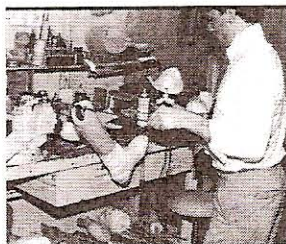
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## The Lower Limb Acts Like a Compound Pendulum

- Period of passive swing depends upon the mass moment of inertia of the shank, so:

$$T = 2\pi \sqrt{I/mgh}$$

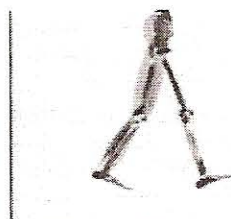


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## During Walking

- At least 60° of knee flexion needed in initial swing to clear toe
- At normal walking speed, knee flexion is passive
  - > No muscles are active across the knee joint



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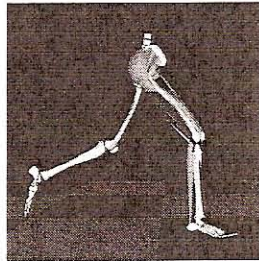
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## During Running or Sprinting

- More knee flexion is needed
- Gait cycle is much shorter
- Swing has to be accomplished much more rapidly



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## How Is This Accomplished?

- $KE = M \times V^2$
- More speed requires more power
- Pendulum's swing must be controlled
  - i.e., knee flexion must be restrained and hip flexion augmented
  - A mechanism is needed to accomplish this

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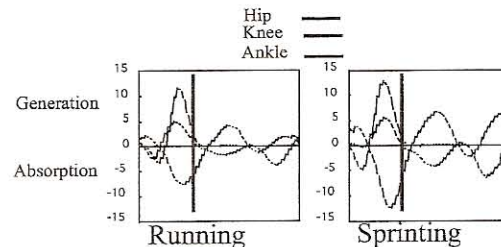
## Power Sources for Swing

- Triceps surae in terminal stance (A-2)
- Hip flexors in pre-swing and initial swing (H-3)
- Contralateral hip extensors (H-1) may also assist by pulling the body forward

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## Power Curves



## In Rapid Gait

- Increased power [(A-2) + (H-3)] ipsilat & (H-1) contralat.
  - Increases body's linear velocity
  - Increases acceleration and arc of knee flexion
  - No effect on the period of swing
- Bi-articular muscle action (R.F. + Hams)
  - Dampens and reduces period of shank's swing
  - Augments range and rate of hip flexion



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## In Slow Gait

- Decreased power
  - Body's linear velocity slows
  - Decreased acceleration and arc of knee flexion
- Bi-articular muscle action (R.F. + Hams)
  - Alters arc of knee flexion
  - Potential to also increase hip flexion



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? Same as off ui  
Swing = oscillation



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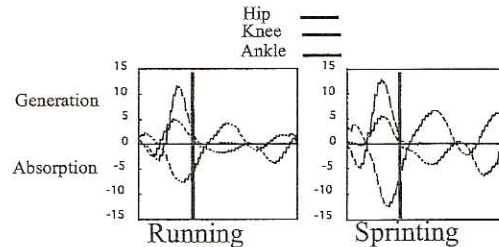
## Overlaying Hip & Knee Moments and Powers...

- Demonstrates energy transfer activity of R.F. & Hams
- Illustrates energy conservation that results

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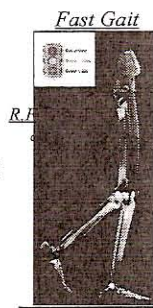
## Power Curves



## Initial Swing

- Its purposes are to:

- Provide sufficient flexion to clear the plantarflexed toe
- Decelerate the rate and range of knee flexion in rapid gait
- Increase the range of knee flexion in slow gait

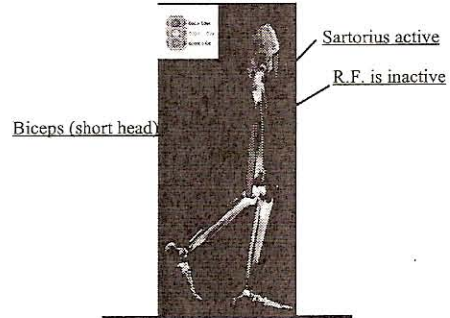


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## Initial Swing

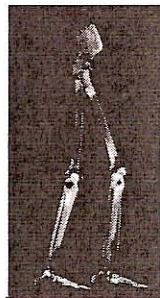
### Slow Gait



## Mid-Swing

- Essentially a "switching period" between initial swing and terminal swing
- No muscles are active across the knee in mid-swing

A "Switching Period"

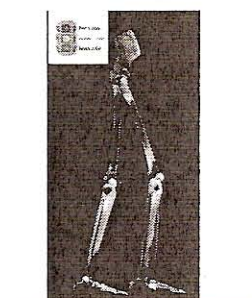


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## MidSwing

A "Switching Period"



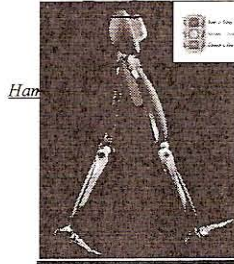
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### Terminal Swing

■ Its purposes are to :

- Bring the knee back to full extension by the end of swing
- Decelerate the rate of extension in rapid gait
- Augment extension in slow gait



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### Terminal Swing

#### Fast Gait

Hamstring  
decelera

They're transferring

Like a Door S

