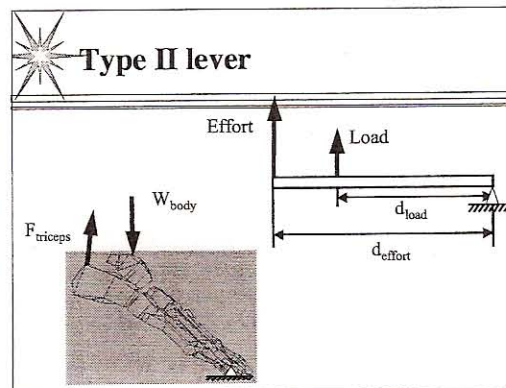
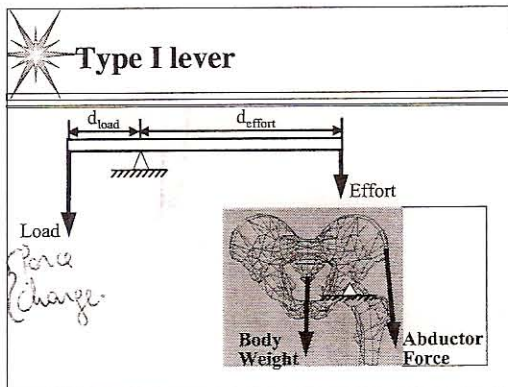
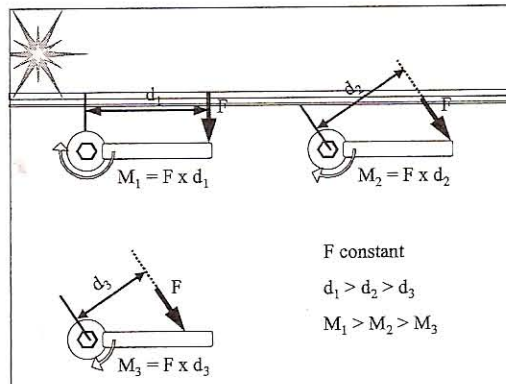
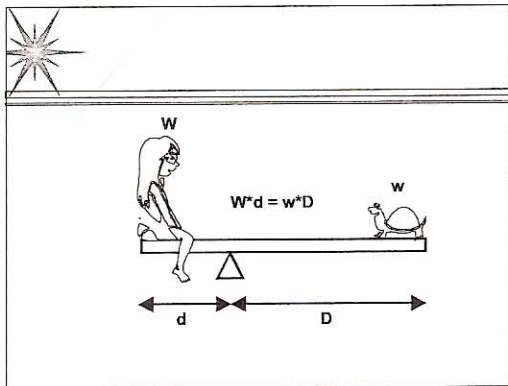


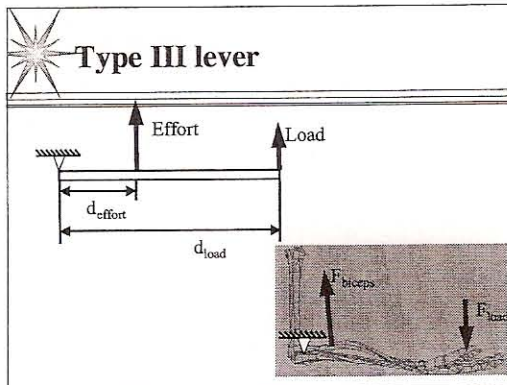
## Lever Arm Dysfunction in Pathologic Gait

Tom F. Novacheck, MD  
Gait Course 2007

## What is a "lever-arm" or "moment-arm"?

- > It is one of the components of a moment
- >  $\text{Moment} = \text{Force} \times \text{lever-arm}$
- > It is a "Distance" from a point to a force
- > Perpendicular to line of action of the force





### Remember!

- > The two primary purposes of moments (muscle force  $\times$  lever arm distance)
  - > stance phase stabilization (support moment)
  - > propulsion (acceleration)
    - > of body segments
    - > of body mass

### A brief review of ambulation

- > How does movement occur?
  - > The skeleton provides the levers required for movement
  - > Muscles and ground reaction forces provide the required power
  - > The joints serve as the hinges

### How is erect posture maintained?

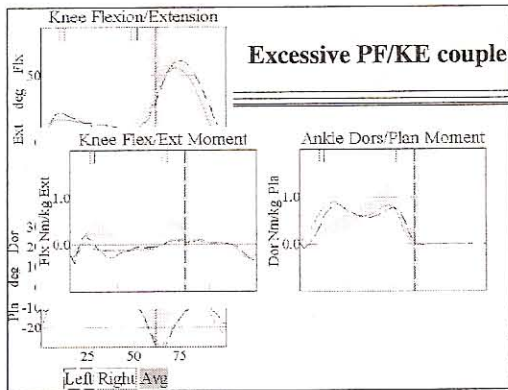
- > David Winter
  - > The plantarflexors always contribute  $\approx 50\%$  of the total support
  - > The hip and knee extensors contribute the remaining 50%, but their relative contributions vary depending upon speed, terrain, fatigue, etc.

### How do the plantarflexors act to maintain knee extension?

- > The soleus locks the ankle during the mid-portion of stance.
- > This allows the ground reaction force to exert an extension moment against the knee.

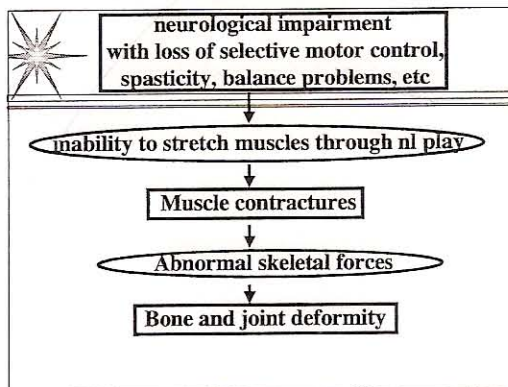
### The Plantarflexion/Knee Extension Couple





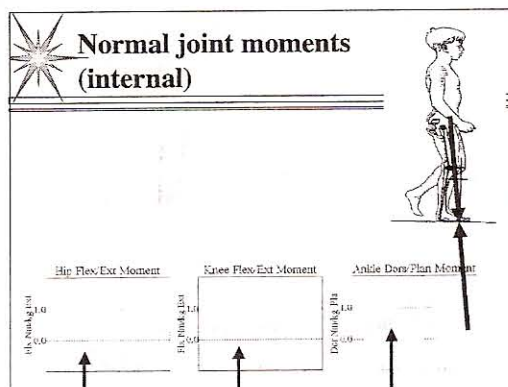
## What happens when a child has cerebral palsy?

either inadequate force and/or  
“lever-arm dysfunction”



## In ambulation, moments are of two types:

- > Internal, where forces are produced by:
  - > Muscles
  - > Tendons
  - > Ligaments
- > External, where forces are produced by
  - > Ground Reaction Force
  - > segmental weight




## What is “lever-arm dysfunction”?

- > the “lever-arm” portion of the moment is abnormal
- > Several types of lever-arm dysfunction exist:
  - > Short lever-arm
  - > Flexible lever-arm
  - > Mal-rotated lever-arm
  - > Unstable fulcrum
  - > Positional lever-arm dysfunction

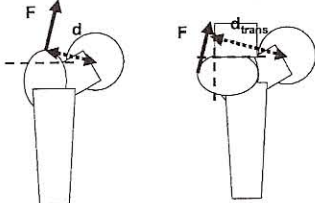


### Short Lever-arm:

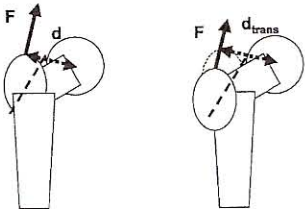
- > Examples
  - > Midfoot amputation
  - > Coxa Valga or coxa breva
- > Effect -- Since  $M = F \times d$ , If the lever-arm length is cut in half ( $d/2$ ), then  $M$  is cut in half as well



The diagram shows a vertical leg segment with a horizontal dashed line representing the axis of rotation. A force vector  $F$  is applied at a distance  $d$  from the axis, perpendicular to the lever arm.




The diagram shows two scenarios of a flexible lever arm. In the first, a force  $F$  is applied at a distance  $d$  from the axis. In the second, the lever arm is curved, and the distance  $d_{trans}$  is the horizontal component of the distance from the axis to the point of application of the force.



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### Flexible Lever-arm:

- > Example -- Pes planovalgus
- > The rubber crowbar

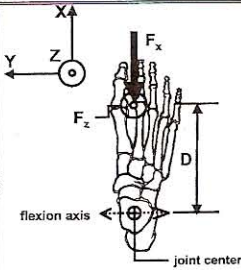


The photo shows a person standing on a platform, using a rubber crowbar to measure the distance from the axis of rotation to the point of application of the force.

### Malrotated lever-arm:

- > Examples
  - > External tibial torsion
  - > Femoral anteversion
- > Effect
  - > Primary moment is reduced (knee extension moment)
  - > Unwanted moments introduced
    - > external rotation
    - > valgus

### Neutral Foot Progression



The diagram shows a foot in a coordinate system with X, Y, and Z axes. The joint center is at the origin. The distance from the joint center to the point of application of the force is  $D$ . The force vector  $F$  is applied at a distance  $D$  from the joint center. The flexion axis is indicated.

$$M_{flex/ext} = F_z \cdot D$$

$$M_{var/val} = 0$$

$$M_{iR/eR} = 0$$

### External Tibial Torsion

$$M_{flex/ext} = F_z * d$$

$$M_{var/val} = F_z * h$$

$$M_{iR/eR} = F_x * h$$

joint center

### Unstable fulcrum:

- > Example -- Dislocated or subluxated hip
- > Effect -- Since there is no stable pivot point, no effective moment can be generated

### Positional lever-arm dysfunction

- > Example -- bi-articular hamstrings (hip and knee)
- > Effect
  - > In extension (erect stance), the length of the lever-arm of the hamstrings at the hip is relatively longer than the length of the lever-arm at the knee. Hence, the extensor moment at the hip is relatively larger than the flexor moment at the knee.
  - > In flexion (crouch), the length of the lever-arm of the hamstrings at the hip is relatively shorter than the length of the lever-arm at the knee. Hence, the extensor moment at the hip is relatively smaller than the flexor moment at the knee

### Positional lever-arm dysfunction

### Positional lever-arm dysfunction

Muscle Force

Dorsiflexion

Joint Center

Plantarflexion

Lever Arm

### Compensation

Pelvis

Abductor Demand


d\_abductor

d\_weight

Weight


Force Reduction

Weight shift



**Frequently, lever-arm dysfunction exists at several levels**

- Example – The “Malignant Mal-Alignment Syndrome”
  - Knee is internally rotated to line of progression 2° to femoral anteversion
  - External rotation of the foot 2° to tibial torsion &/or pes valgus
  - The result is a severe reduction of the magnitude of the plantarflexion/knee extension couple and instability of the knee in stance.



**Loss of PF/KE Couple 2° to:**

- Lever-arm dysfunction &/or soleus insufficiency (soleus is too long)
  - Muscle elongates with time and growth
  - Gastrocnemius is often contracted (short)
  - 2° contractures of hip and knee flexors
  - Triceps Vastii are long
  - Rectus femoris is of normal length or contracted
  - Ultimately, contracture of posterior knee capsule develops over time