

Electromyography in Clinical Practice: Interpretation and Applications

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■ Outline:

- ◆ Background
- ◆ Resulting Information
- ◆ EMG as part of understanding motion
- ◆ Biarticular Muscles
- ◆ EMG and TX Decision-making

1. Definition

- Electromyography is the measurement of electrical activity of a contracting muscle
- The contracting muscle produces muscle action potentials
- The EMG signal represents the summation of all muscle action potentials

Single
action
potential

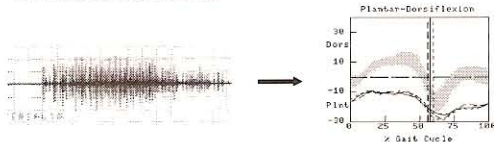


Summated
action
potentials



- If there is an EMG signal, there is muscle fiber action that can generate a force:

- ◆ Initiate movement
- ◆ Control movement

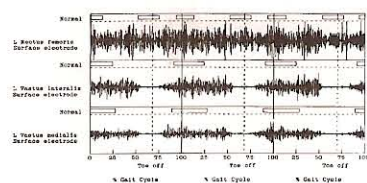


- If there is no EMG signal:

- ◆ There is no muscle contraction
- ◆ A muscle force may be present due to contracture
 - ◆ Limits movement

2. Resulting Information

- ON and OFF patterns of muscle contraction during repetitive motion such as gait



- Comparison to "typical" muscle patterns

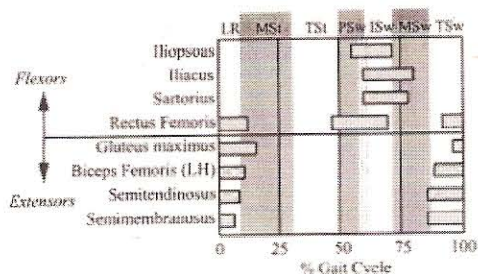
However... One must consider "Typical" Muscle Function and Variability

- Typical (normal) EMG patterns (and pathological)
 - ◆ To know what is pathological
- Typical EMG patterns vary
 - ◆ Stride to stride
 - ◆ Person to person
- Plasticity (Winter, 1990)
 - ◆ Many combinations of muscle contractions result in similar motion

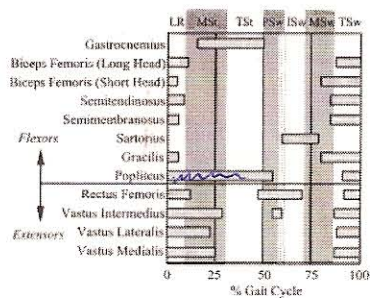
Note: typical EMG represented as a "bar" is misleading

We could answer

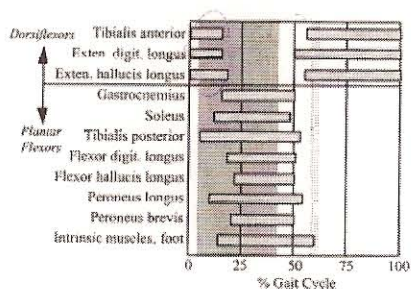
Typical Muscle Function at the Hip



Typical Muscle Function at the Knee



Typical Muscle Function at the Ankle



How is EMG activity “described” versus typical?

- Early onset
- Prolonged
- Continuous
- Out of phase – reverse phase
- Under active - inactive
- Co-active (simultaneous agonists and antagonists)

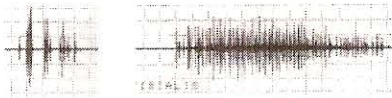
“Atypical” EMG: Next Question is why?

- Is atypical muscle activity
 - primary (motor control issues)?
 - result of position (crouch in stance)?
 - result of joint motion (response to quick stretch)?
- Cause or effect? Not always easy to determine.
- Swing phase abnormalities are easiest to interpret as there is less positional response

Swing phase reflect more the pathology.

Information from activities other than gait

- Muscle contribution beyond gait during
 - ◆ Rest
 - ◆ Changing positions: reclined/sitting/standing
 - ◆ Voluntary contractions: agonists/antagonists
 - ◆ Passive range of motion – quick stretch



Can we think about muscle function in another way?

How do muscles function in the human body?

- Muscle contraction = force
- Force (F) acts at a distance (d) from the center of rotation
- Human body = joint moment (torque)

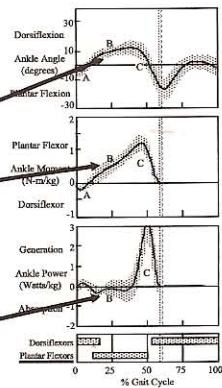


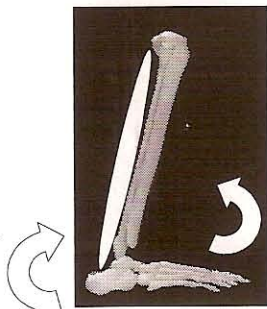
3. EMG as a part of understanding function

- Combining EMG, motion, moment and power data provides us with an improved understanding of the biomechanical basis of movement
- All treatment should have a biomechanical basis

Ankle – sagittal plane

- Mid stance (B)
 - ◆ Ankle dorsiflexion
 - ◆ Net internal plantar flexor moment provided by the ankle plantar flexors
 - ◆ Power absorption results due to eccentric contraction of the ankle plantar flexors



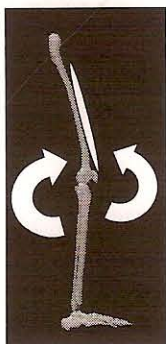
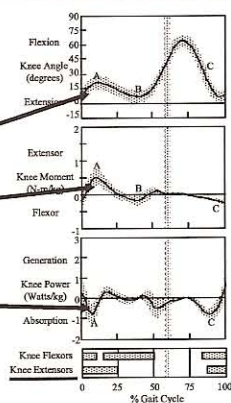


Eccentric Contraction

Knee – sagittal plane

■ Loading response (A)

- ◆ Knee flexes
- ◆ Net internal knee extensor moment provided by the knee extensors
- ◆ Power absorption results due to the eccentric contraction of the knee extensors

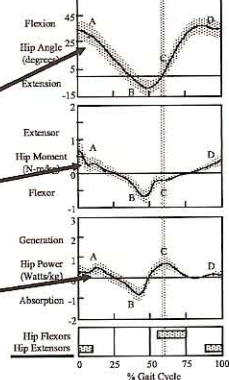


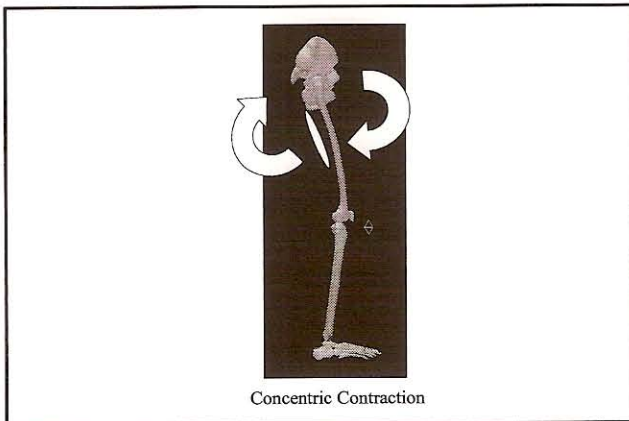
Eccentric Contraction

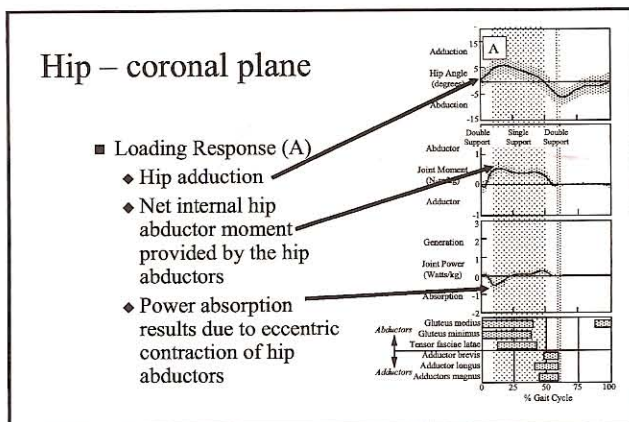
Hip – sagittal plane

■ Loading Response (A)

- ◆ Hip extension
- ◆ Net internal hip extensor moment provided by the hip extensors
- ◆ Power generation results due to concentric contraction of hip extensors







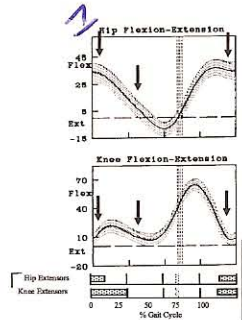
What about...

bi-articular muscles?



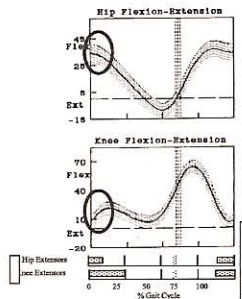
2. Bi-articular Muscles

- Hamstrings and Rectus femoris
- How are these muscles functioning?
- Both active during loading response and terminal swing
- Loading response
 - ◆ Hip extension - knee flexion
- Mid stance/Terminal swing
 - ◆ Hip extension - knee extension



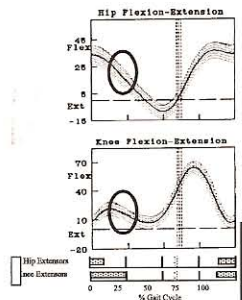
Shortening or lengthening?

- Rectus femoris
 - ◆ Lengthens proximally
 - ◆ Lengthens distally
- Hamstrings
 - ◆ Shortens proximally
 - ◆ Shortens distally



Simultaneous shortening/lengthening

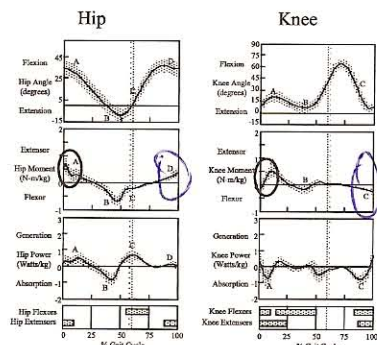
- Rectus femoris
 - ◆ Lengthens proximally
 - ◆ Shortens distally
- Hamstrings
 - ◆ Shortens proximally
 - ◆ Lengthens distally



A person

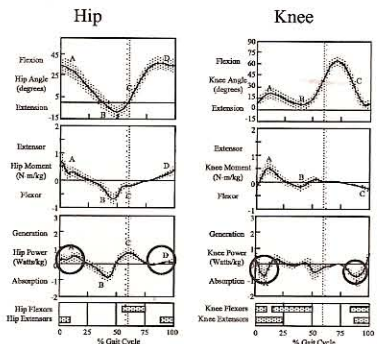
Joint moment data?

- Provides information about which muscle group is dominant
- Loading response (A)
 - ◆ extensors at hip
 - ◆ extensors at knee



Power generation and absorption

- Loading response (A)
 - ◆ Generation hip
 - ◆ Absorption knee
- Terminal swing (D)
 - ◆ Generation hip
 - ◆ Absorption knee
- Energy transfer?

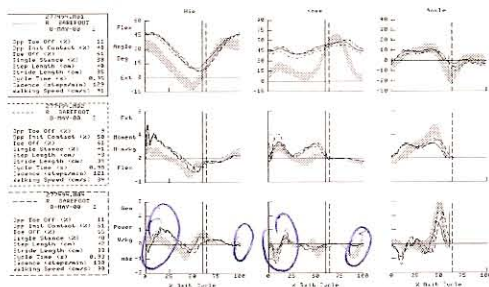


Bien van correlations.

Role of bi-articular muscles????

- EMG data tells us what muscles are contracting
- Moment data provide some information about which muscle groups are dominant ("amplitude" of EMG)
- Power data provides information about type of contraction (eccentric vs. concentric) at a joint and a mechanical basis for energy transfer
- We still have a lot to learn about the coordination of bi-articular muscles

Bi-articular muscles and pathology?



Energy transfers are not as efficient?



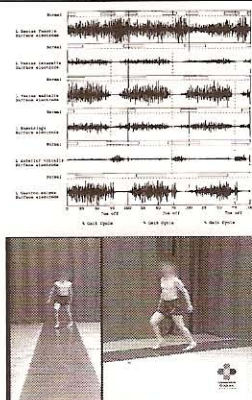
4. EMG and Treatment Decision-making

- The **ONLY** way to know for sure when a muscle is contracting during simple to complex motions
- Augments assessment of abnormal muscle tone vs. tightness
- Unexpected “understanding” of pathology
- Allows for more specificity in treatment decision-making

ALLOWS US TO TEST OUR “POSSIBLE CAUSE” ASSUMPTIONS

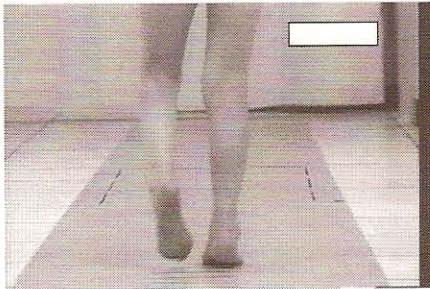
EMG is Integral to Understanding Joint Function – e.g. knee

- Rectus femoris, vastus medialis and lateralis
 - ◆ Swing phase function
- Hamstrings medial and lateral
 - ◆ Terminal swing function
 - ◆ Stance phase
- Kinematics/kinetics/clinical exam



■ Think about your TX assumptions

Can EMG validate your assumptions?



What is the cause of the equinovarus – supination deformity?

Limitations

- Measure of electrical not mechanical activity
- EMG signal alone does not provide information as to whether a contraction is:
 - ◆ Concentric
 - ◆ Eccentric
 - ◆ Isometric

Limitations con't

- EMG relationship to force is not straightforward
- Must determine if the muscle(s) are producing a deforming force with motion data or observation
- EMG as a unique tool is therefore somewhat limited
- Joint moment data provides a reference with respect to EMG amplitude
- It is rarely practical/possible in the clinical setting to record from all muscles of interest = assumptions

5. Examples of EMG and TX Decisions

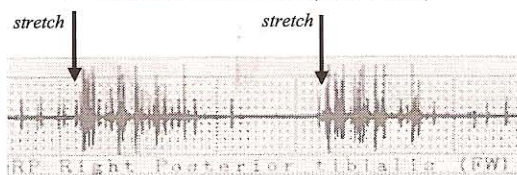
- Understanding muscle tone
 - ◆ Intervention for abnormal muscle tone
- Understanding impaired isolated voluntary control
- Surgical intervention
 - ◆ Evaluation for treatment decision-making and for treatment outcomes

Understanding Muscle Tone

- Muscle response to stretch can be better understood with EMG
 - ◆ Prolonged EMG (abnormal) to no EMG signal (typical)
 - ◆ Normal muscle = no resistance
 - ◆ no EMG signal
 - ✱ ◆ Spastic muscle = resistance
 - ◆ prolonged EMG signal (slow stretch)
 - ◆ clonus EMG signal (rapid stretch)
- Resistance and no EMG response = "stiffness"
- Utility in the older patient with cerebral palsy
 - ◆ Spasticity versus rigidity?

■ Evaluation of Muscle Tone

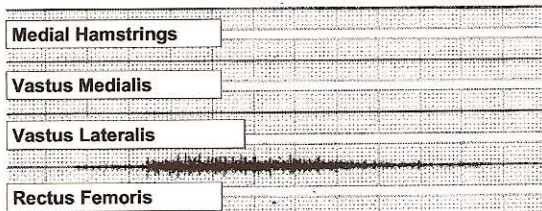
- ◆ Which muscles are "spastic" vs. tight
- ✱ ◆ Response to slow stretch in all directions
 - ◆ = sustained contraction (not normal)



Slow passive forefoot eversion – posterior tibialis signal

ELY Test (rapid passive knee flexion)

- Assessment of resistance to knee flexion (spasticity of the quadriceps)



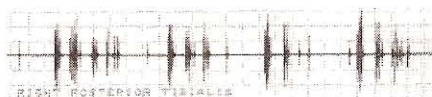
■ Evaluation of Muscle Tone (con't)

- ◆ Response to rapid stretch

◆ = Positive clonus response



Rapid passive ankle dorsiflexion – gastrocnemius signal



Rapid passive forefoot eversion – posterior tibialis signal

* Evaluation of Spasticity

- Simultaneous EMG recording during passive muscle stretch
- ◆ Synergists or individual muscle response?

→ muscle tone vs clonus

Rectus Femoris vs. Quadriceps

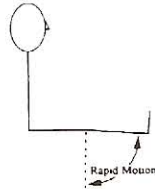
knee knee
flexion extension

Medial Hamstrings

Vastus Medialis

Vastus Lateralis

Rectus Femoris



(Öunpuu et al., Gait and Posture, 1997)

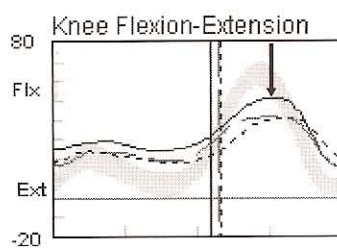
Surgical Decision-making

■ Case 1

Reduced knee flexion in swing

Dx: Cerebral Palsy

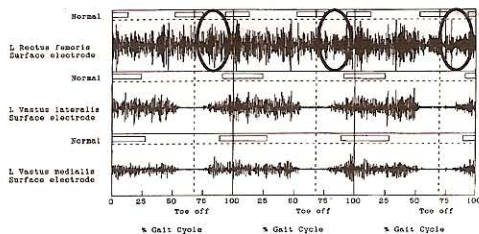
Cause?



Treatment Decision-making Paradigm:

- Hypothesis: Rectus femoris activity in mid swing = reduced peak knee flexion in swing
- If true:
 - ◆ Rectus Femoris Transfer = Maintained or increased peak knee flexion in swing
- Note: there would be no basis for the rectus femoris transfer if this muscle was not active in mid swing (abnormal firing pattern)

Rectus femoris active in mid swing



Relevant findings:

- Rectus femoris activity in mid swing
- Vastus medialis and lateralis are not active in initial to mid swing
- Knee sagittal plane kinematic supports need for rectus femoris procedure

Treatment Plan:

- rectus femoris transfer

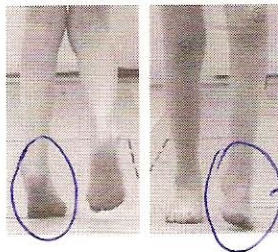
active.

Surgical Decision-making

■ Case 2

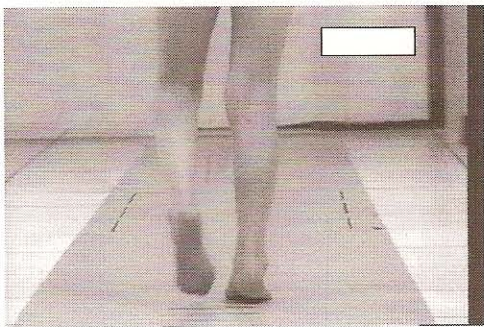
Foot/ankle deformity – Cerebral Palsy

- Dynamic hind foot varus in stance and swing
- Hypothesis:
 - 1 ♦ Posterior tibialis “over” activity
 - 2 ♦ Simultaneous anterior tibialis and plantar flexor spasticity?
- Forefoot supination deformity in swing
- Hypothesis:
 - ♦ Relative anterior tibialis “over” activity



Supination

Pre Surgical Evaluation

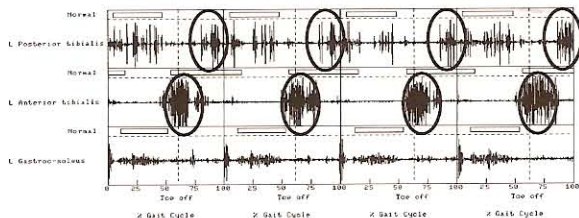


Relevant Clinical Findings:

- Minimal plantar flexor contracture (-5 degrees with the knee extended, 5 degrees with the knee flexed)
- Inability to isolate voluntary ankle motion
- Positive confusion test (forefoot supinated)
- Forefoot inversion/eversion/plantar flexion are full
- Hind foot inversion/eversion are full
- No fixed adductus of the forefoot

en prolate, evolution unique

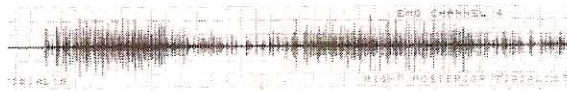
Posterior/Anterior tibialis activity



(EMG data collected with fine wire electrodes for the top 2 channels)

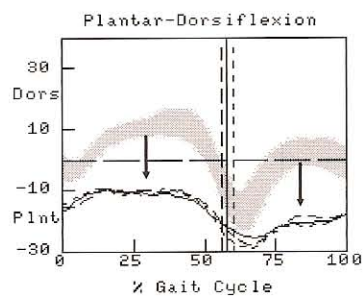
Other relevant EMG findings:

- Continuous activity of the posterior tibialis on rapid passive forefoot eversion



- No activity noted in the anterior tibialis on rapid stretch
- Sustained clonus noted in the gastrocnemius only
- Moderate gastrocnemius spasticity (dynamic equinus significant)

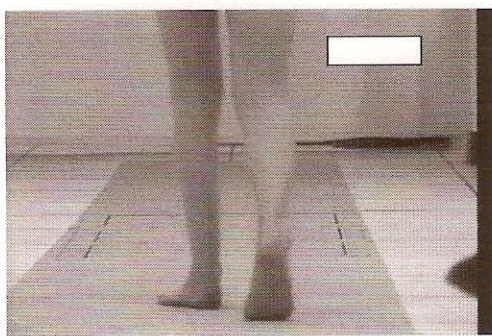
Ankle sagittal plane kinematics



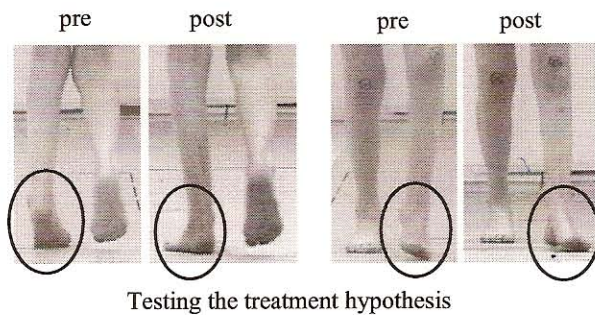
Treatment Plan?

- Posterior tibialis lengthening?
 - ◆ Indications...(motion, FW EMG)
- Split anterior tibialis transfer?
 - ◆ Indications...(motion, FW EMG)
- Gastrocnemius lengthening?
 - ◆ Indications...(motion, clinical exam)

Post Surgical Evaluation



Surgical Outcomes Evaluation



Surgical Decision-making

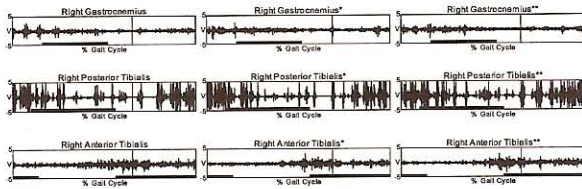
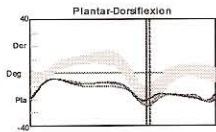
■ Case 3

Foot Function and the Posterior Tibialis

What is causing this foot/ankle problem?



Foot Function and the Posterior Tibialis

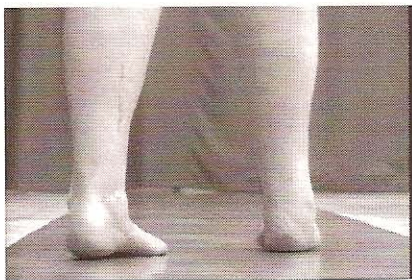


Surgical Decision-making

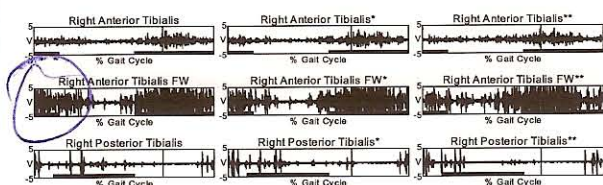
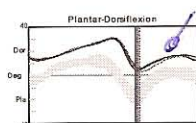
■ Case 4

Foot Function and the Posterior Tibialis

What is causing this foot/ankle problem?



Foot Function and the Posterior Tibialis

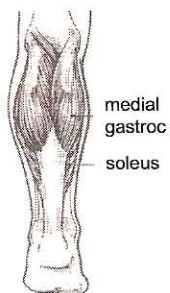


Tone Management Decision-making

- Botox A decision-making

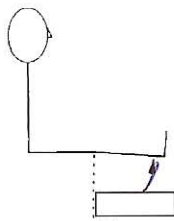
BOTOX A - treatment of spastic muscles

- Consideration for plantar flexor injection – where and how much?
- Medial vs. lateral gastrocnemius vs. soleus injections?
- Equal dosage in each?



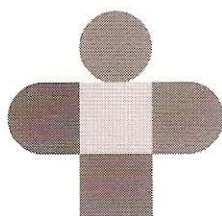
BOTOX A

- EMG role in providing more specific diagnostics
- Differentiate EMG response between medial/lateral gastroc and soleus
 - ◆ Stretch (rapid and slow)
 - ◆ Ankle dorsiflexion & knee extension
 - ◆ Positioning and movements (standing, toe rise)
 - ◆ Gait



- Clinical gait analysis is about defining and treating abnormal movement.
- Abnormal movement is caused by abnormal muscle function.
- Multiple combinations of muscle function can lead to the same movement.
- Therefore, we need to measure muscle function to correct abnormal movement.

Thank You – Questions?



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