

Clinical Electromyography: Data and Interpretation Guides

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- Outline:
 - ◆ Definition
 - ◆ Resulting Information
 - ◆ Typical Muscle Function
 - ◆ Data Collection
 - ◆ Interpretation Guides
 - ◆ EMG in Persons with Cerebral Palsy
 - ◆ EMG and TX Decision-making
 - ◆ Examples of EMG and TX Decisions

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



How is activity “described” versus typical?

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

“Atypical” EMG: How do we interpret it?

- Is abnormal 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 the easiest to interpret as there is less positional response

Resulting Information con't

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



3. Typical Muscle Function – some concepts

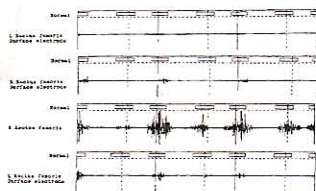
- Most muscles active at transition times
 - ◆ silent mid stance and mid swing
- Onset and termination of muscle activity gradual
- Muscle activity is present prior to the need for force generation
- Muscles contract eccentrically or lengthen prior to concentric contraction

"Typical" Muscle Function and Variability

- EMG patterns vary
 - ◆ Stride to stride
 - ◆ Person to person
- Plasticity (Winter, 1990)
 - ◆ Many combinations of EMG result in similar motion

Rectus Femoris

- primary burst begins in terminal swing
 - ◆ generate knee extensor force in preparation for IC
- continues through loading response and mid stance
 - ◆ control knee flexion - assist in knee extension
- secondary burst peaks just after toe off
 - ◆ assists in hip flexion
 - ◆ decelerates knee flexion



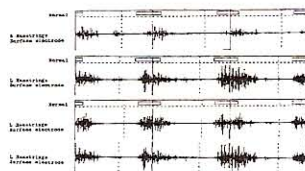
Vastus Lateralis and Medialis

- have similar activity patterns
- one major peak of activity TSW through LR
 - ◆ generate knee extensor force in preparation for IC
 - ◆ control knee flexion
 - ◆ assist in knee extension



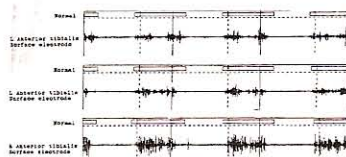
Hamstrings (Medial and Lateral)

- have similar activity patterns
- primary burst of activity beginning in terminal swing
 - ◆ decelerate knee extension
- continues through mid stance
 - ◆ hip extension
- some persons there is a second burst at toe off
 - ◆ assist in knee flexion



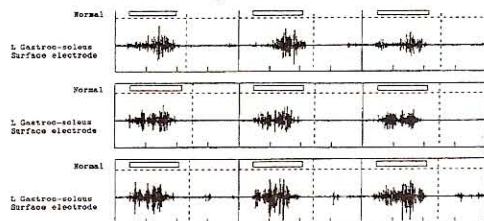
Anterior Tibialis / Extensor Digitorum Longus

- have similar activity patterns
- two bursts of activity are present
- just prior to TO and continues through ISW
 - ◆ ankle dorsiflexion
- increasing again in TSW and loading response
 - ◆ generate force in preparation for IC and control the lowering of the forefoot

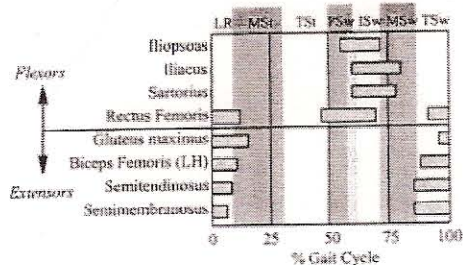


Gastrocnemius (Medial and Lateral)

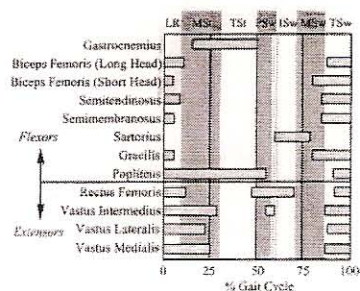
- have similar activity patterns
- beginning at about 10% of the gait cycle through TST
 - ◆ initially control the forward motion of the tibia
 - ◆ then assists in active plantar flexion of the ankle



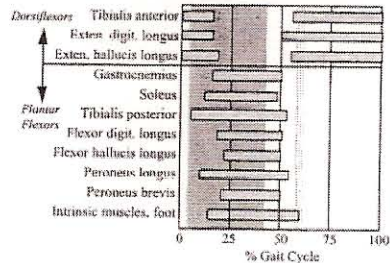
Typical Muscle Patterns During Gait: Hip Joint



Typical Muscle Patterns During Gait: Knee Joint



Typical Muscle Patterns During Gait: Ankle Joint



4. EMG Data Collection

- Electrode Placement
 - ◆ Skin preparation – clean
 - ◆ No dead skin or skin lotion
 - ◆ Electrode skin interface required excellent contact
 - ◆ No thick hair
 - ◆ Connecting wires
 - ◆ Orient upwards
 - ◆ Minimum slack but no pulling

Surface versus Fine Wire EMG?

- Provide the same information
- Fine wire is necessary for deep muscles
- Fine wire is necessary for smaller surface muscles
 - ◆ Reduced cross-talk
- Better option in obese patients
- Larger surface muscles can be evaluated using surface electrode techniques – no consensus on this point

FW and Surgical Decision-making

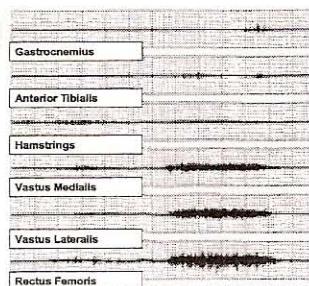
- Neuromuscular etiologies
- Lower extremity deformities
 - ◆ Foot and ankle deformity
 - ◆ Equinovarus
 - ◆ Supination
 - ◆ Cavus, claw-toes
- Upper extremity deformities
 - ◆ Shoulder, elbow, wrist and finger deformities

Fine wire EMG signal - caveats

- More variable signal than surface EMG
- Sampling from a smaller representation of the overall muscle
- Electrode itself may have an impact on muscle function
 - ◆ Cramping/pain
- Electrode may not stay in muscle of interest
 - ◆ Retest insertion after data collection

Signal Quality Checks

- Does muscle and electrode channel match?
- No muscle activity at rest? (few exceptions)
- Signal when muscle contracts?
- Cross-talk tests
 - ◆ Confirm activity on electrode is consistent with desired muscle

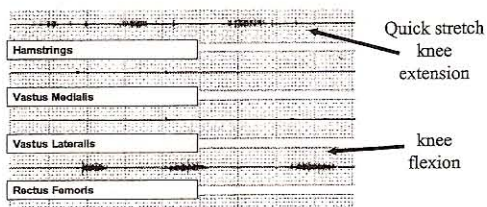


Cross-talk tests

- Rectus Femoris on Vastus Medialis and/or Lateralis Electrode Signals
 - ◆ Function = knee extension
 - ◆ Response = activity on three muscles
- ◆ Function = hip flexion
- ◆ Response = activity on rectus femoris only

Cross-talk tests

- When isolated movement is not possible
 - ◆ Quick stretch of specific muscle can assist

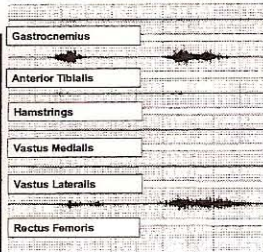
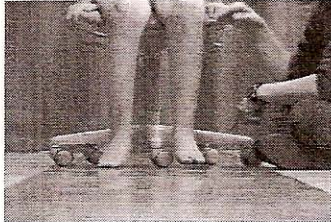


Cross-talk tests

- When isolated movement is not possible
 - ◆ Synergistic motion can provide information about what muscles are active
- Confusion test – hip flexion in seating position
 - ◆ Anterior tibialis active?
 - ◆ Simultaneous plantar flexor activity?

Confusion Test

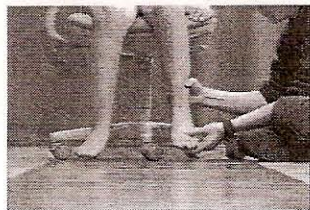
Positive test: Hip flexion with simultaneous ankle dorsiflexion



Other tests with electrodes.....

■ Evaluation of Voluntary Control

- ◆ Assessment of all voluntary ankle movements non-weight bearing
- ◆ Which muscles are recruited – “co-activity”



Confirming Expected Muscle Activity

- Assessment of signal quality
- Assessment of pathology
- What is typical for “toe-walking”
 - ◆ Defining
 - ◆ cause versus effect
 - ◆ primary versus secondary

Other tests with electrodes.....

■ Weight bearing

- ◆ Relaxed standing
 - ◆ Muscles required for stability
 - ◆ Increased EMG amplitude from crouch to straight leg standing
- ◆ Toe standing/heel standing/forefoot inversion-eversion
 - ◆ What muscles are recruited?

■ Gait

- ◆ Typical
- ◆ Heel, toe etc.

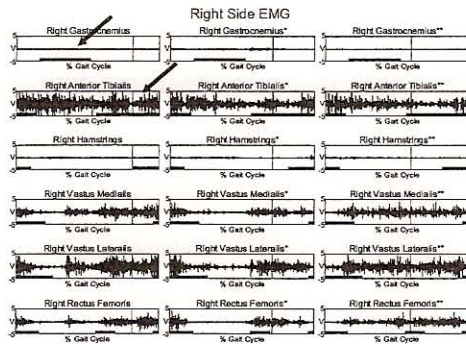
Typical Person – Drop foot



Typical Person - Toe Walking



Typical Person - Heel Walking



5. Interpretation Guides for EMG Data

- Interpretation of the EMG Signal:
 - ◆ raw format
 - ◆ multiple strides
 - ◆ normal EMG patterns
 - ◆ typical findings for pathology
 - ◆ weight bearing position or swing?
 - ◆ joint contracture and role in producing force
 - ◆ are all muscles surrounding joint monitored with EMG?

Trouble Shooting EMG Data

- Use raw EMG signal
- Signal processing will "cover-up" errors
- Artifact in the EMG signal may look like a "typical" EMG signal

Multiple strides gastrocnemius (patient with CP)



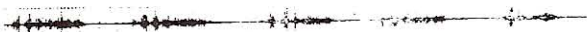
repetitive pattern

Multiple strides gastrocnemius (patient with CP)

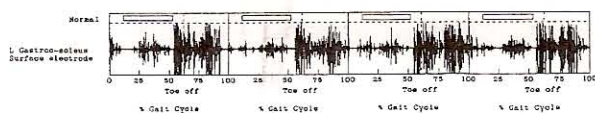
Variable muscle firing patterns



Replacement with further cleaning of skin over gastrocnemius muscle results in a typical repetitive pattern that should be observed in patients with CP



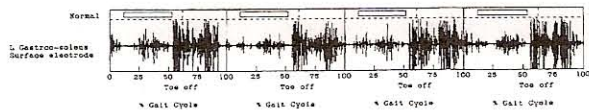
Gastrocnemius EMG



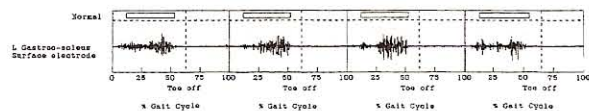
What is wrong with this EMG signal?

typical repetitive pattern

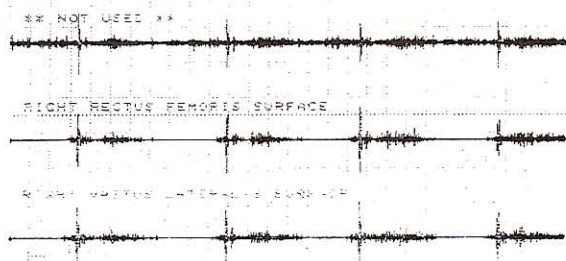
Atypical muscle firing patterns



• Replacement with further cleaning of skin over gastrocnemius muscle results in a typical repetitive pattern

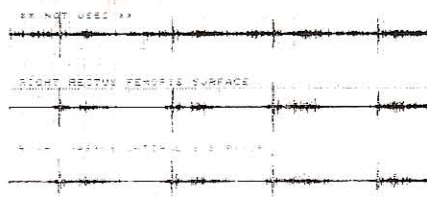


What does the spike suggest in these signals?



Spike artifact

- Simultaneous EMG spike in several channels
- Occurs at regular intervals
- Timing corresponds with initial contact
- Amplitude of spike is much greater than the rest of the signal



5 gait cycles

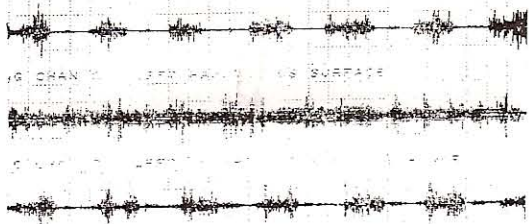


What is the problem with this EMG signal from one muscle?

Clue = Change of signal content



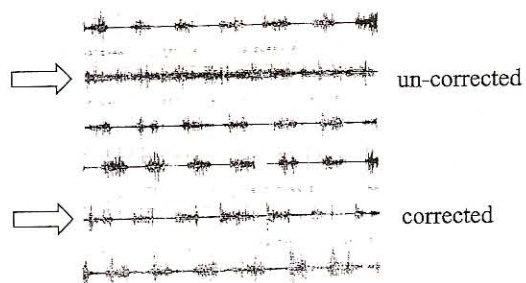
EMG from 3 quadriceps



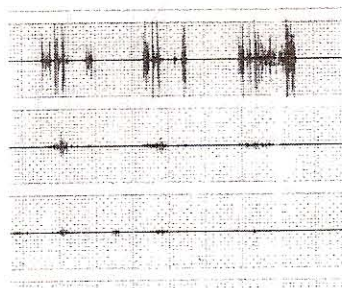
Which signal is a problem?

incorrect

Continuous artifact during signal detection

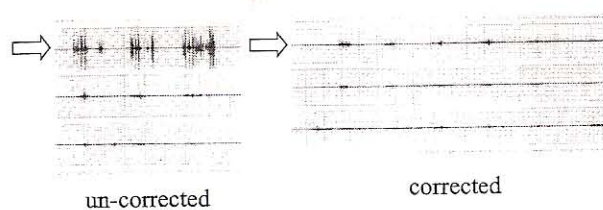


EMG from 3 quads



Which signal
is a
problem?

Variable amplitudes for synergistic muscles

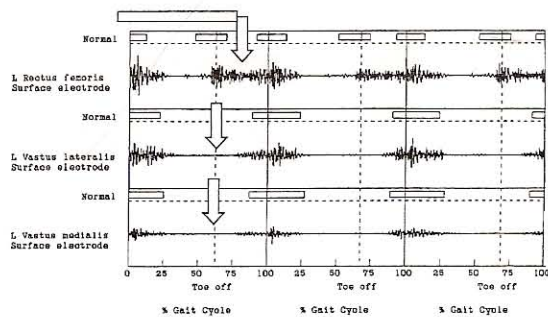


6. Typical EMG Patterns in the Child with CP

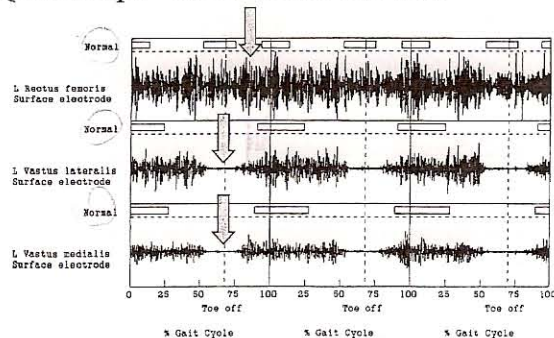
Characteristics:

- Co-activity between agonists and antagonists
- Prolonged activity \Rightarrow continuous activity
- Out of phase activity
- Is abnormal muscle activity primary (motor control issues) or a result of position (crouch in stance) or joint motion (response to quick stretch)?
- Cause or effect?

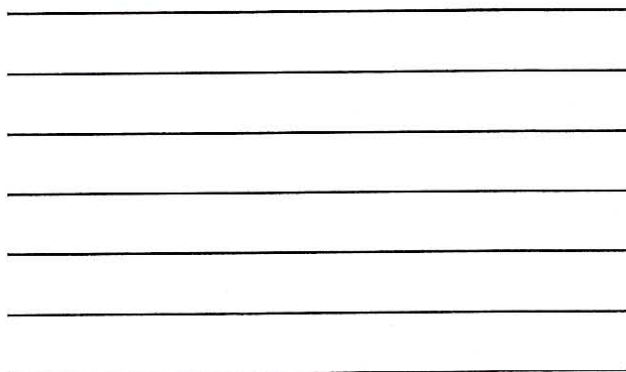
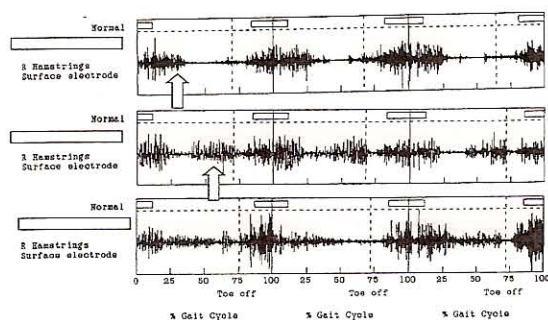
Quadriceps – rectus femoris and vasti



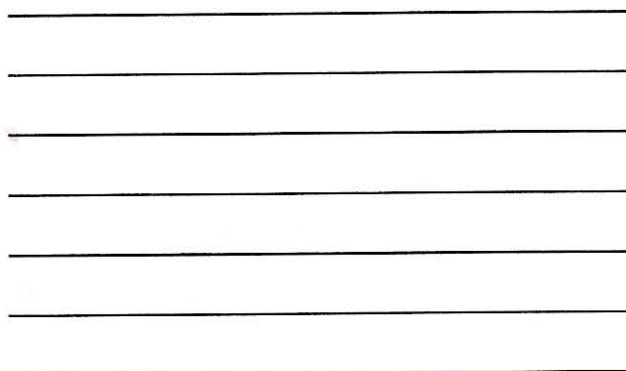
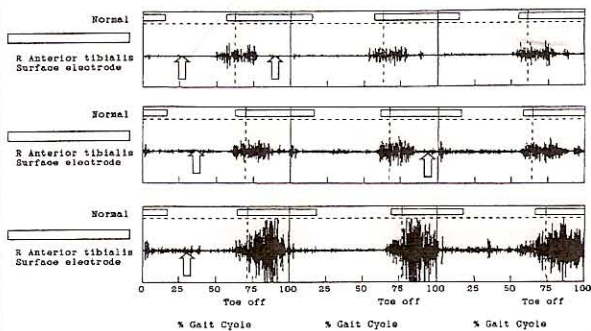
Quadriceps - rectus femoris and vasti



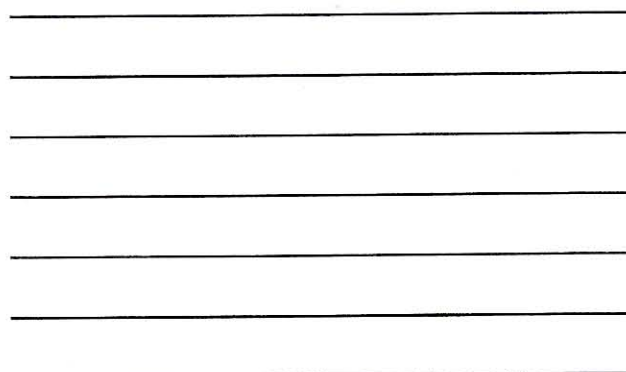
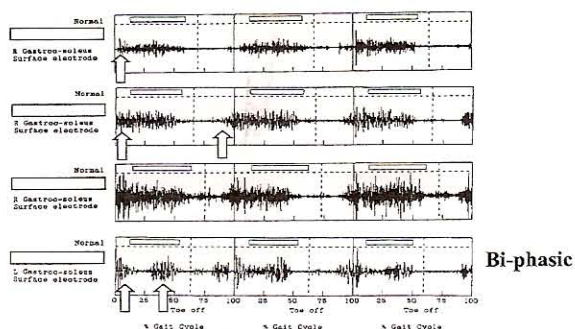
Hamstrings



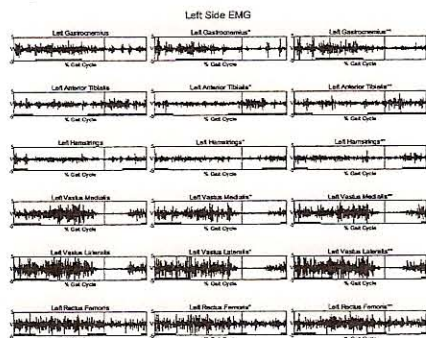
Anterior tibialis



Gastrocnemius



“Significantly” Involved Patient



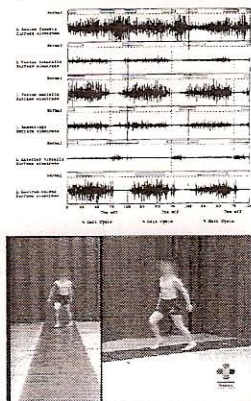
7. EMG and Treatment Decision-making

- 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

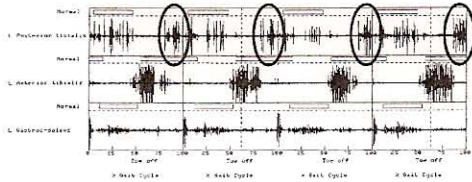
EMG is Integral to Understanding Joint Function – e.g. knee

- 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?



- EMG reduces the assumptions made with regards to muscle function

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

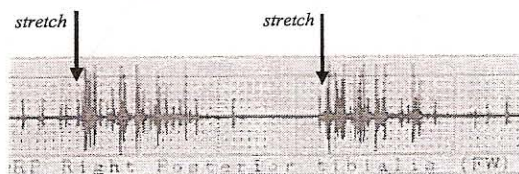
- EMG relationship to force is not straightforward
- Must determine if the muscle(s) are producing a deforming force with motion data or observation
- EMG as a unique tool is therefore somewhat limited
- Joint moment data provides a reference with respect to EMG amplitude
- It is rarely practical/possible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

8. Examples of EMG and TX Decisions

- Understanding muscle tone
 - ◆ Intervention for abnormal muscle tone
- Understanding impaired isolated voluntary control
- Document atypical on/off patterns
 - ◆ Evaluation for surgical decision-making and outcomes

■ Evaluation of Muscle Tone

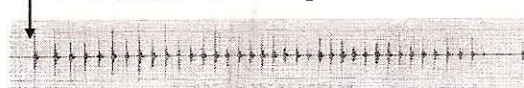
- ◆ Which muscles are “spastic” vs. tight
- ◆ Response to slow stretch in all directions
 - ◆ = sustained contraction (not normal)



Slow passive forefoot eversion – posterior tibialis signal

■ Evaluation of Muscle Tone (con't)

- ◆ Response to rapid stretch
 - ◆ = Positive clonus response



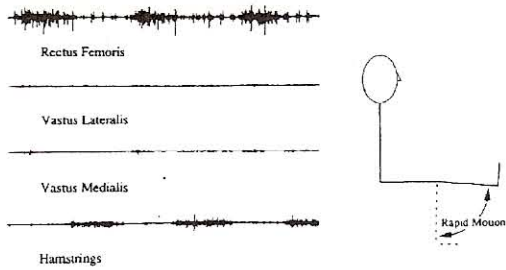
Rapid passive ankle dorsiflexion – gastrocnemius signal



Rapid passive forefoot eversion – posterior tibialis signal

Rectus Femoris vs. Quadriceps

knee knee
flexion extension



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

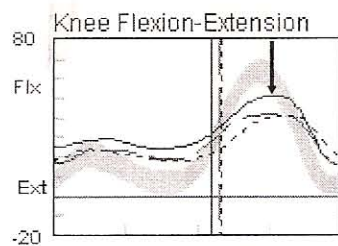
Surgical Decision-making

■ Case 1

Reduced knee flexion in swing

Dx: Cerebral Palsy

Cause?



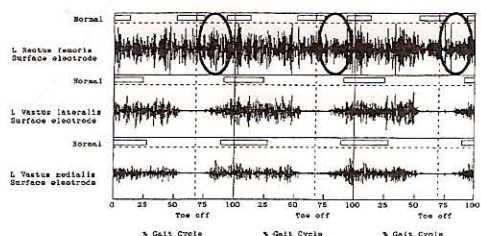
↓ peak flex 6%

Q. transfer DA

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:

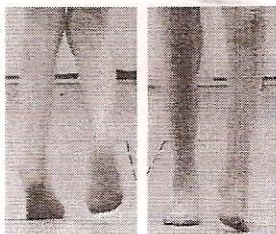
- rectus femoris transfer

Surgical Decision-making

■ Case 2

Foot/ankle deformity – Cerebral Palsy

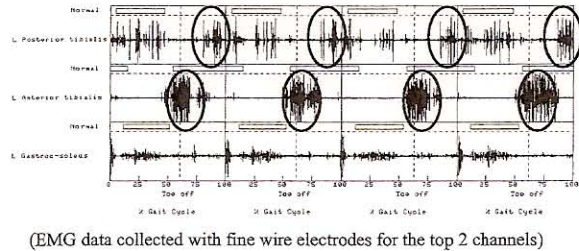
- Dynamic hind foot varus in stance and swing
- Hypothesis:
 - ◆ Posterior tibialis “over” activity
 - ◆ Simultaneous anterior tibialis and plantar flexor spasticity?
- Forefoot supination deformity in swing
- Hypothesis:
 - ◆ Relative anterior tibialis “over” activity



Pre Surgical Evaluation

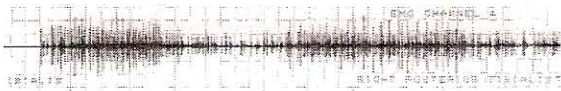


Posterior/Anterior tibialis activity



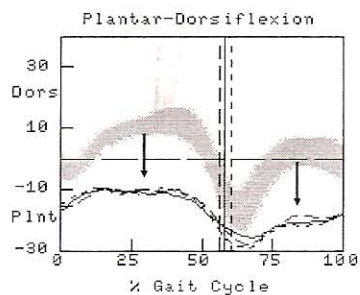
Other relevant EMG findings:

- 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

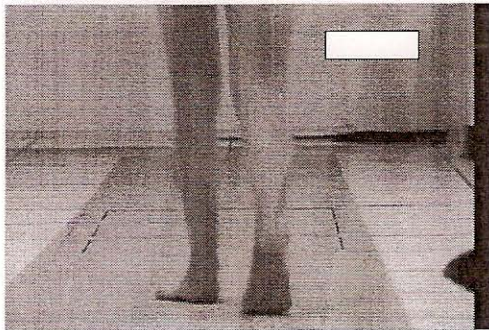


Treatment Plan?

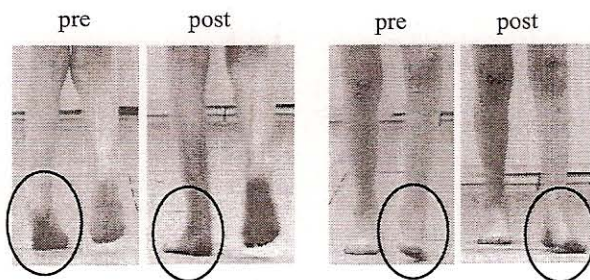
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- Posterior tibialis lengthening?
 - ◆ Indications...(motion, FW EMG)
- Split anterior tibialis transfer?
 - ◆ Indications...(motion, FW EMG)
- Gastrocnemius lengthening?
 - ◆ Indications...(motion, clinical exam)

Post Surgical Evaluation



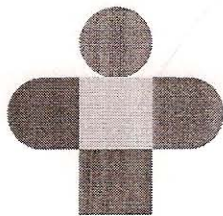
Surgical Outcomes Evaluation



Testing the treatment hypothesis

- 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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