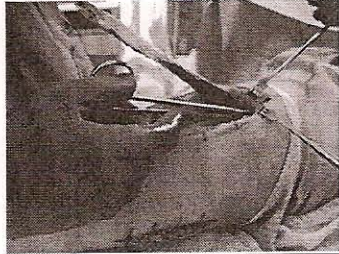


TREATMENT PRINCIPLES: SOFT TISSUE SURGERY IN CHILDREN WITH CP

JON R. DAVIDS, M.D.
MOTION ANALYSIS
LABORATORY



SOFT TISSUE SURGERY

- RELATE STRUCTURE TO FUNCTION
- NORMAL MUSCLE/TENDON
 - Design Parameters
- MUSCLE/TENDON IN CP
 - Pathophysiology

SOFT TISSUE SURGERY

- FUNCTIONAL DEFORMITIES OF MUSCLE/TENDON IN CP
- SURGICAL INTERVENTIONS
 - Principles
- COMMON SURGICAL PROCEDURES
 - Specific Indications

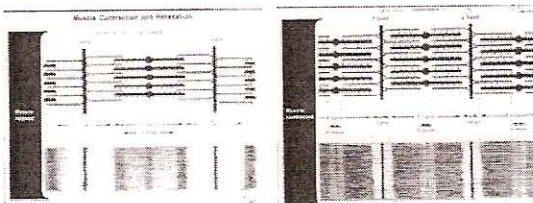
SOFT TISSUE SURGERY

- HIERARCHY OF SKELETAL MUSCLE STRUCTURE
- MUSCLE BELLY
 - Muscle Fiber
- MYOTENDINOUS JUNCTION
- TENDON
- TENDON-BONE JUNCTION



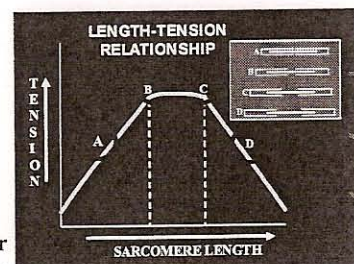
SOFT TISSUE SURGERY

- MUSCLE BELLY
- SARCOMERE
 - ACTIN, MYOSIN, CROSSBRIDGE LINKAGES



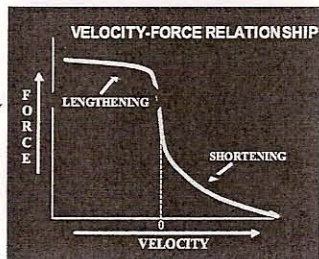
SOFT TISSUE SURGERY

- MUSCLE
- PHYSIOLOGY / MECHANICAL PROPERTIES
- LENGTH - TENSION RELATIONSHIP
 - Narrow Range for Optimal Function



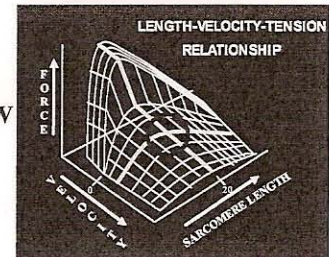
SOFT TISSUE SURGERY

- **VELOCITY - TENSION RELATIONSHIP**
 - Rate of Cross Bridge Attachment
- **CONCENTRIC ACTIVITY (SPEED)**
 - Force Inversely Proportional to Velocity
- **ECCENTRIC ACTIVITY (STRENGTH)**
 - Force Independent of Velocity



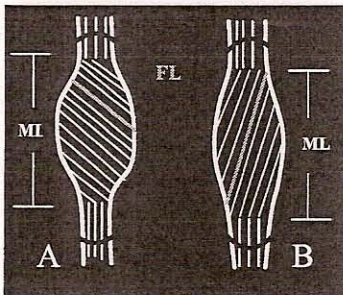
SOFT TISSUE SURGERY

- **LENGTH - VELOCITY - TENSION RELATIONSHIP**
- **NARROW WINDOW**
 - For Optimal Function
- **MOST SENSITIVE TO**
 - High Velocity, Concentric



SOFT TISSUE SURGERY

- **MYOARCHITECTURE**
- **FIBER LENGTH (FL)**
 - Number of Sarcomeres in Series
- **FL / MUSCLE LENGTH (ML) RATIO**
 - Increased FL / ML →
 - Increased Velocity, Excursion
 - Decreased FL / ML →
 - Increased Force Generation



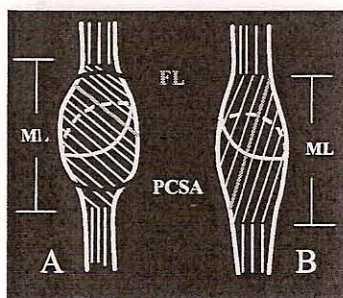
SOFT TISSUE SURGERY

- **MYO-ARCHITECTURE**
- **PENNATION ANGLE**
 - Muscle Fiber Alignment
 - Relative to Axis of Force Generation



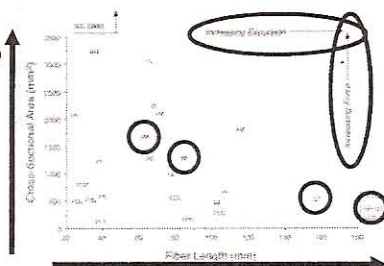
SOFT TISSUE SURGERY

- **PHYSIOLOGIC CROSS SECTIONAL AREA (PCSA)**
 - Muscle Volume, Fiber Length, Pennation
- **INCREASED PCSA**
 - Increased Force Generation



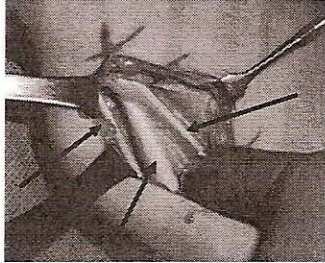
SOFT TISSUE SURGERY

- **MYOARCHITECTURE**
- **FIBER LENGTH**
 - Excursion
- **INCREASED PCSA**
 - Force



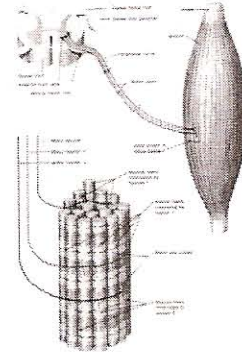
SOFT TISSUE SURGERY

- MYOARCHITECTURE
- DESIGN CHARACTERISTICS
 - Distinct
- FUNCTION
 - Distinct
- SENSITIVITY TO LENGTHENING
 - Distinct



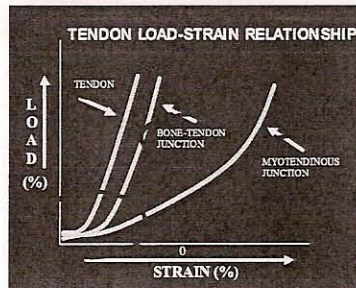
SOFT TISSUE SURGERY

- OTHER DESIGN PARAMETERS
- FIBER TYPE DISTRIBUTION
 - Speed and Endurance
- MOTOR UNIT DISTRIBUTION
 - Relative Motor Control



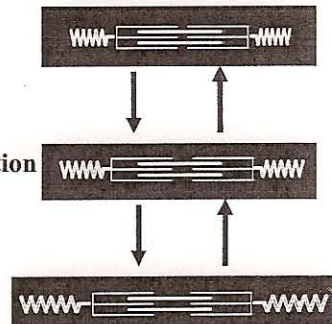
SOFT TISSUE SURGERY

- TENDON
- LOAD - STRAIN RELATIONSHIP
 - Low Load →
 - Increased Elongation
 - Myotendinous Junction > Tendon, Tendon-Bone Junction



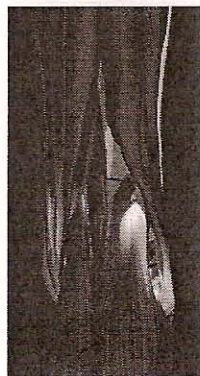
SOFT TISSUE SURGERY

- TENDON FUNCTION
 - Compliance
 - Shock Absorption
 - Return Stored Elastic Strain Energy
 - Increased Functional Range



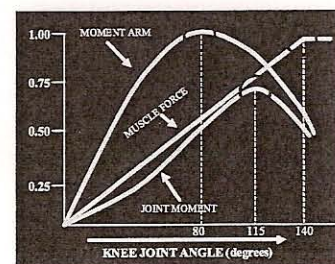
SOFT TISSUE SURGERY

- TENDON ARCHITECTURE
- TENDON LENGTH (TL) / FL RATIO
 - Increased TL / FL
 - Increased Whole Muscle Stiffness



SOFT TISSUE SURGERY

- JOINT MOMENT PRODUCTION
 - = MF X DIST
 - Contribution
 - Muscle Function
 - Joint Properties
 - Complex Interaction



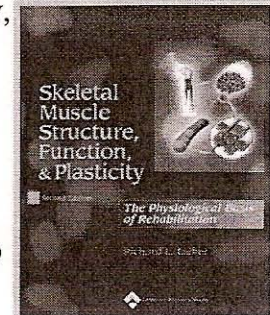
SOFT TISSUE SURGERY

- STRUCTURE - FUNCTION RELATIONSHIP
- ANATOMY, PHYSIOLOGY, BIOMECHANICS
- OPTIMAL FUNCTION
 - Multiple Variables
 - Narrow Window



SOFT TISSUE SURGERY

- MUSCLE PHYSIOLOGY, BIOMECHANICAL PROPERTIES
- SKELETAL MUSCLE STRUCTURE, FUNCTION, AND PLASTICITY, 2ND ED
 - Richard L. Lieber, PhD
 - Williams & Wilkins, 2002



SOFT TISSUE SURGERY

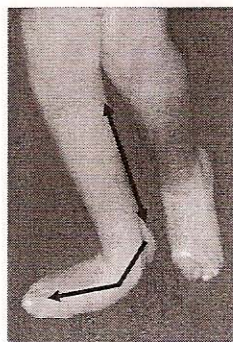
- MUSCLE / TENDON IN CEREBRAL PALSY
- CHRONIC SHORTENING (AGONIST)
 - Decreased Number of Sarcomeres, FL
- CHRONIC STRETCH (ANTAGONIST)
 - Increased Number of Sarcomeres, FL
 - Increased Tendon Length

SOFT TISSUE SURGERY

- MUSCLE IN CEREBRAL PALSY
 - Decreased FL, PCSA →
 - Decreased Velocity, Excursion
 - Decreased Force Generation
- TENDON IN CEREBRAL PALSY
 - Increased Length →
 - Increased Whole Muscle Stiffness

SOFT TISSUE SURGERY

- MUSCLE/TENDON - JOINT INTERACTION IN CP
- MOMENT PRODUCTION COMPROMISED
 - Decreased Force Generating Capacity
 - Suboptimal Length, Velocity, Tension Parameters
 - Decreased MA
 - Skeletal Lever Deficiency



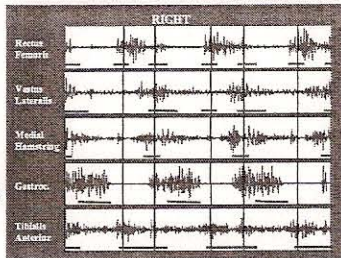
SOFT TISSUE SURGERY

- MUSCLE/TENDON UNIT IN CP
 - Functional Deficits
- SEQUENTIAL, PROGRESSIVE
 - Dynamic
 - Myostatic
 - Continuum



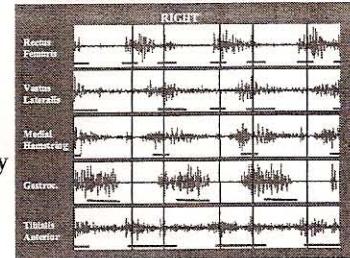
SOFT TISSUE SURGERY

- DYNAMIC DEFORMITY
- TIMING, MAGNITUDE
 - Overactive (Spastic Agonist)
 - In/Out of Phase
 - Continuous
 - Underactive (Antagonist)
 - In Phase



SOFT TISSUE SURGERY

- DYNAMIC DEFORMITY
- TIMING, MAGNITUDE
- DYNAMIC EMG
 - Electrical Activity
 - Not Directly Proportional To Strength



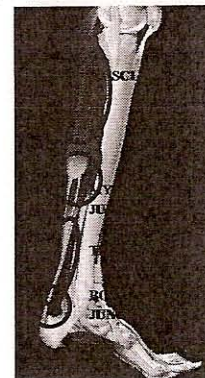
SOFT TISSUE SURGERY

- MYOSTATIC DEFORMITY
 - Structural
 - Too Short/Long
 - Constant



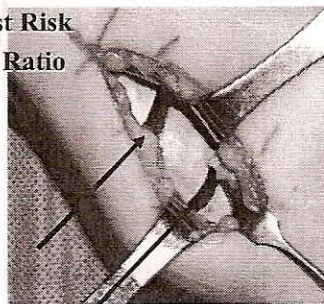
SOFT TISSUE SURGERY

- SURGICAL TECHNIQUES
- RELEASE
 - Myotomy, Tenotomy
- LENGTHEN
 - Recession, Z Lengthening
- TRANSFER



SOFT TISSUE SURGERY

- WEAKENING
 - Muscles at Greatest Risk
 - Decreased FL/ML Ratio
 - Increased PCSA
- RECESSION PREFERRED
 - ? Less Disruption FL/ML Ratio
 - Preserve Tendon Integrity



SOFT TISSUE SURGERY

- SURGICAL PRINCIPLES
- DYNAMIC - OVERACTIVE, IN PHASE
 - Weaken, Lengthen
 - Transfer (Split)
- DYNAMIC - OVERACTIVE, OUT OF PHASE
 - Transfer (Complete)

SOFT TISSUE SURGERY

- SURGICAL PRINCIPLES
- DYNAMIC - OVERACTIVE, CONTINUOUS
 - Weaken, Lengthen

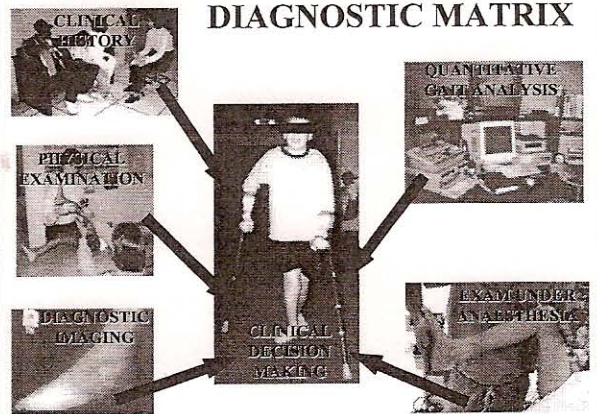
SOFT TISSUE SURGERY

- SURGICAL PRINCIPLES
- MYOSTATIC - TOO SHORT
 - Lengthen, Weaken
- MYOSTATIC - TOO LONG
 - Shorten
 - Correct Skeletal Lever Deficiency

SOFT TISSUE SURGERY

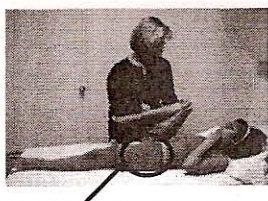
- SURGICAL PRINCIPLES
- MUSCLE ACTIVITY : SKELETAL ALIGNMENT
- SINGLE SKELETAL SEGMENT
 - No Segmental Malalignment
 - Transverse Plane
- MULTIPLE SKELETAL SEGMENTS
 - Segmental Malalignment
 - Passively Correctable

DIAGNOSTIC MATRIX



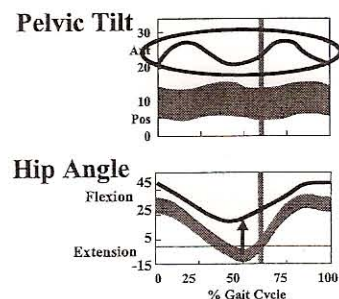
AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- ILIOPSOAS RECESSION
- PHYSICAL EXAMINATION
 - THOMAS TEST, STAHEL TEST



AMBULATORY CP: MUSCULOSKELETAL SURGERIES

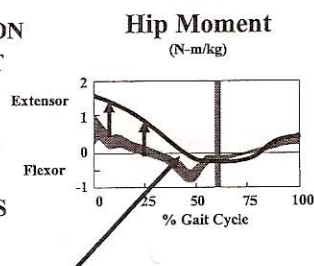
- ILIOPSOAS RECESSION
- DIAGNOSTIC IMAGING
 - NONE
- QUANTITATIVE GAIT ANALYSIS
 - KINEMATICS
 - MULTIPLE POSSIBLE CAUSES



o Hip flexion contracture
o approx 30°

AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- ILIOPSOAS RECESSION
- QUANTITATIVE GAIT ANALYSIS
 - KINETICS
 - INCREASED EXT MOMENT
 - DELAYED CROSS OVER
 - MULTIPLE POSSIBLE CAUSES



AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- ILIOPSOAS RECESSION
- CONTROVERSIAL
 - ALMOST ALWAYS!
 - NOVACHEK ET AL, JPO 22:158-164, 2002
 - HARDLY EVER!
 - DELUCA ET AL, JPO 18:712-718, 1998

AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- ILIOPSOAS RECESSION
- CURRENT INDICATIONS
 - HIGH KNEEL WALK
 - HIP FLEXION CONTRACTURE
 - MYOSTATIC DEFORMITY
 - > 30 DEGREES



AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- ILIOPSOAS RECESSION
- CURRENT INDICATIONS
 - HIGH KNEEL WALK
 - HIP FLEXION CONTRACTURE
 - MYOSTATIC DEFORMITY
 - > 30 DEGREES

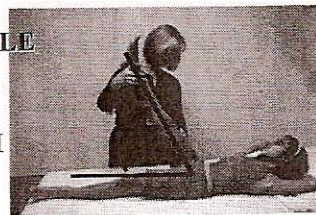


AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- MEDIAL HAMSTRING LENGTHENING
- CLINICAL HISTORY
 - UNABLE TO STAND STRAIGHT
 - WALKS WITH KNEES BENT
 - KNEE PAIN AND FATIGUE WITH DISTANCE

AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- MEDIAL HAMSTRING LENGTHENING
- PHYSICAL EXAMINATION
 - STRAIGHT LEG RAISE
 - < 60 DEGREES
 - POPLITEAL ANGLE
 - > 40 DEGREES
 - SPASTICITY ON QUICK STRETCH



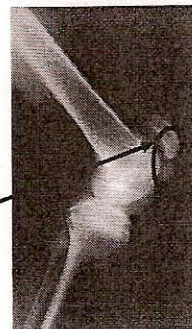
AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- MEDIAL HAMSTRING LENGTHENING
- PHYSICAL EXAMINATION
 - STRAIGHT LEG RAISE
 - < 60 DEGREES
 - POPLITEAL ANGLE
 - > 40 DEGREES
 - SPASTICITY ON QUICK STRETCH



AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- MEDIAL HAMSTRING LENGTHENING
- DIAGNOSTIC IMAGING
 - LATERAL KNEE RADIOGRAPHS
 - PATELLA ALTA
 - FRAGMENTATION

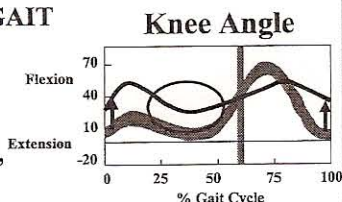


AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- MEDIAL HAMSTRING LENGTHENING
- QUANTITATIVE GAIT ANALYSIS

– KINEMATICS

- INCREASED FLEXION AT IC, TSW
- MST VARIABLE

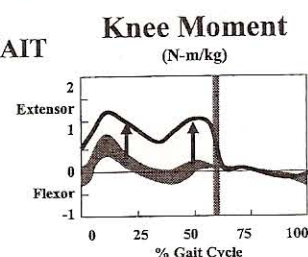


AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- MEDIAL HAMSTRING LENGTHENING
- QUANTITATIVE GAIT ANALYSIS

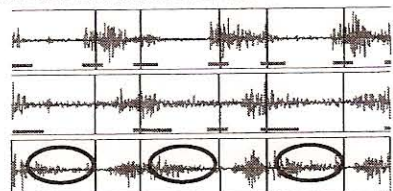
– KINETICS

- INCREASED INTERNAL EXTENSION MOMENT IN ST



AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- MEDIAL HAMSTRING LENGTHENING
- QUANTITATIVE GAIT ANALYSIS
 - DYNAMIC EMG
 - PROLONGED MED HAMSTRINGS IN MST



AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- MEDIAL HAMSTRING LENGTHENING
- EXAMINATION UNDER ANAESTHESIA
 - POPLITEAL ANGLE
 - PALPATE MED VS LAT HAMSTRINGS
 - DISTINCT MYOARCHITECTURE



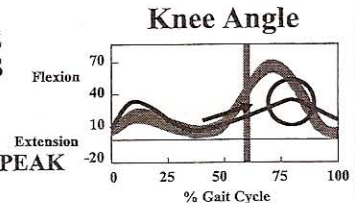
AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- RECTUS FEMORIS TRANSFER
- CLINICAL HISTORY
 - STIFF KNEES, TOE DRAGGING, TRIPPING
- PHYSICAL EXAMINATION
 - PRONE RECTUS TEST (DUNCAN ELY)
 - SLOW, FAST



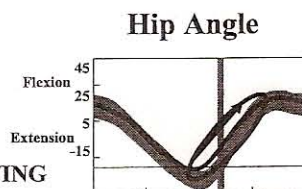
AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- RECTUS FEMORIS TRANSFER
- DIAGNOSTIC IMAGING
 - NONE
- QUANTITATIVE GAIT ANALYSIS
 - KINEMATICS
 - DELAYED, DIMINISHED PEAK FLEX IN SW
 - REDUCED SLOPE ST TO SW



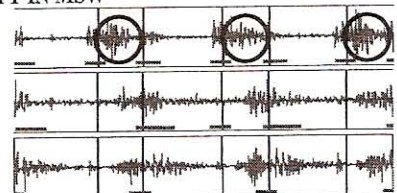
AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- RECTUS FEMORIS TRANSFER
- DIAGNOSTIC IMAGING
 - NONE
- QUANTITATIVE GAIT ANALYSIS
 - KINEMATICS
 - HIP
 - STANCE TO SWING TRANSITION
 - FLEXION SLOPE



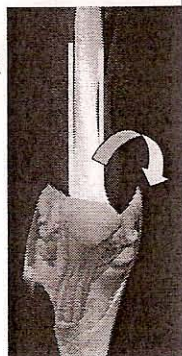
AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- RECTUS FEMORIS TRANSFER
- QUANTITATIVE GAIT ANALYSIS
 - DYNAMIC EMG
 - RF ACTIVITY IN MSW



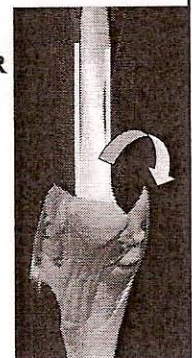
AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- RECTUS FEMORIS TRANSFER
- EXAM UNDER ANAESTHESIA
 - NO INFORMATION
- FUNCTIONAL ANATOMY
 - QUADRICEPS
 - RECTUS FEMORIS
 - TRICEPS FEMORIS



AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- RECTUS FEMORIS TRANSFER
- SURGICAL TECHNIQUE
 - PRINCIPLES OF TENDON TRANSFER
 - EXCURSION
 - PATH OF TRANSFER
 - DIRECTION
 - LEVEL
 - TENSION OF TRANSFER



AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- GASTROCSOLEUS LENGTHENING
- CLINICAL HISTORY
 - TOE WALKING, TOE DRAGGING, TRIPPING, INTOEING



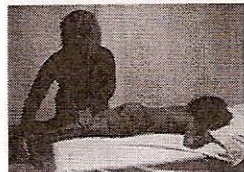
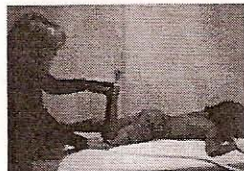
AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- GASTROCSOLEUS LENGTHENING
- PHYSICAL EXAMINATION
 - DIMINISHED ANKLE DF
 - KNEE FLEXED VS EXTENDED
 - CLONUS
 - INCREASED DEEP TENDON REFLEX



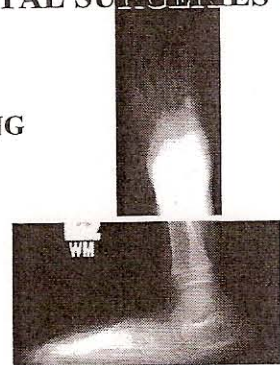
AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- GASTROCSOLEUS LENGTHENING
- PHYSICAL EXAMINATION
 - DIMINISHED ANKLE DF
 - KNEE FLEXED VS EXTENDED
 - CLONUS
 - INCREASED DEEP TENDON REFLEX



AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- GASTROCSOLEUS LENGTHENING
- DIAGNOSTIC IMAGING
 - FOOT SEGMENTAL ALIGNMENT
 - SPASTIC DIPLEGIA
 - PLANOVALGUS



AMBULATORY CP: MUSCULOSKELETAL SURGERIES

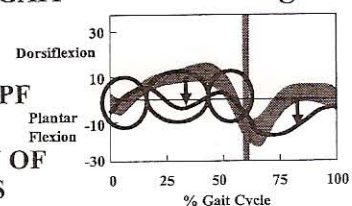
- GASTROCSOLEUS LENGTHENING
- DIAGNOSTIC IMAGING
 - FOOT SEGMENTAL ALIGNMENT
 - SPASTIC HEMIPLEGIA
 - EQUINOVARUS



AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- GASTROCSOLEUS LENGTHENING
- QUANTITATIVE GAIT ANALYSIS
 - KINEMATICS
 - INCREASED PF IN ST / SW
 - DISRUPTION OF ST ROCKERS

Ankle Angle



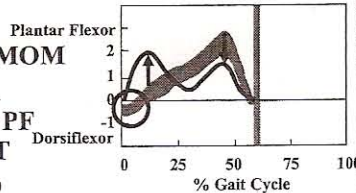
AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- GASTROCSOLEUS LENGTHENING
- QUANTITATIVE GAIT ANALYSIS

– KINETICS

- ABSENT DF MOM IN LR
- INCREASED PF MOM IN MST
- DECREASED PF MOM IN TST

Ankle Moment
(N-m/kg)



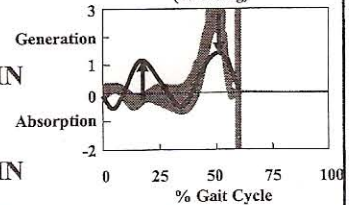
AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- GASTROCSOLEUS LENGTHENING
- QUANTITATIVE GAIT ANALYSIS

– KINETICS

- PREMATURE POWER GEN IN MST
- DIMINISHED POWER GEN IN TST

Ankle Power
(Watts/kg)

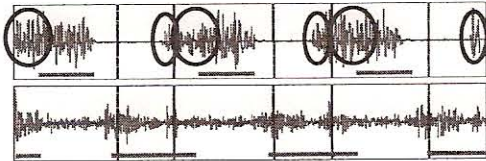


AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- GASTROCSOLEUS LENGTHENING
- QUANTITATIVE GAIT ANALYSIS

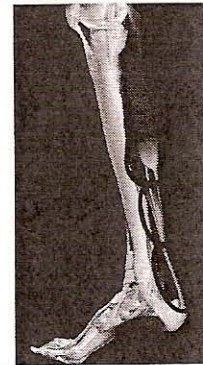
– DYNAMIC EMG

- PREMATURE ACTIVITY IN TST
- PREMATURE ACTIVITY IN LR



AMBULATORY CP: MUSCULOSKELETAL SURGERIES

- GASTROCSOLEUS LENGTHENING
- SURGICAL ANATOMY
 - ZONE 1
 - SELECTIVE GASTROC
 - ZONE 2
 - SELECTIVE GASTROC AND SOLEUS
 - ZONE 3
 - NONSELECTIVE



SOFT TISSUE SURGERY

- STRUCTURE RELATED TO FUNCTION
- NORMAL MUSCLE/TENDON
- MUSCLE/TENDON IN CP
 - Pathophysiology
- FUNCTIONAL DEFORMITIES
 - Sequential, Progressive

