POLITECNICO DI MILANO
DIPARTIMENTO DI BIOINGEGNERIA

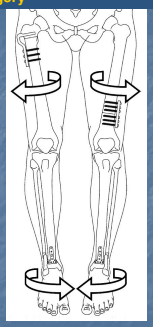
TBM lab
LABORATORIO DI TECNOLOGIE BIOMEDICHE

TRAMA
TRAining in Motion Analysis

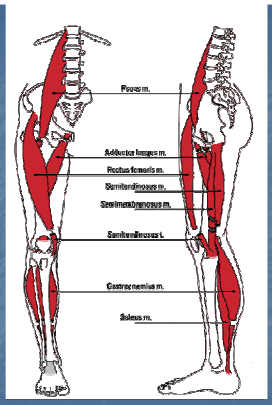
Biomechanical models for the simulation of Orthopaedic surgery

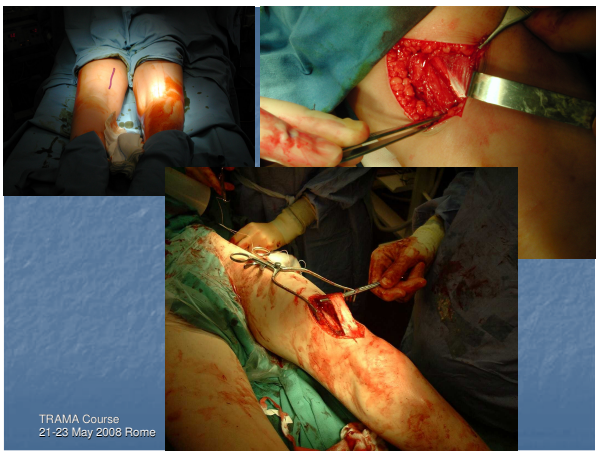
Carlo Frigo
Department of Bioengineering
Laboratory of Movement Biomechanics and Motor Control
TBM Lab, Polytechnic of Milan, Milan, Italy

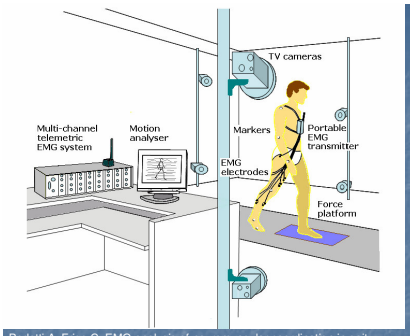
Example: multilevel Functional Orthopaedic Surgery



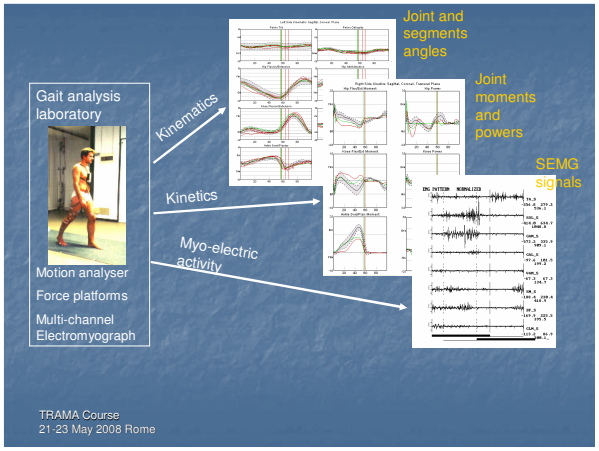
Bache 2003







Pedotti A, Frigo C. EMG analysis of neuromuscular coordination in gait.
In: *Wiley Encyclopedia of Biomedical Engineering*, Metin Akay, (ed), John Wiley & Sons, Inc. –Hoboken (USA), Vol. 4, pages 2562-2573, (2006) DOI: 10.1002/9780471740360.ebs1377



Different modes of getting information from movement analysis

a) Just analysing kinematics, kinetics, and EMG signals
b) Trying to analyse different variables jointly
c) Developing models for further analysis
d) Using additional or alternative movement analysis tools (inertial sensors, wearable devices – not treated here)

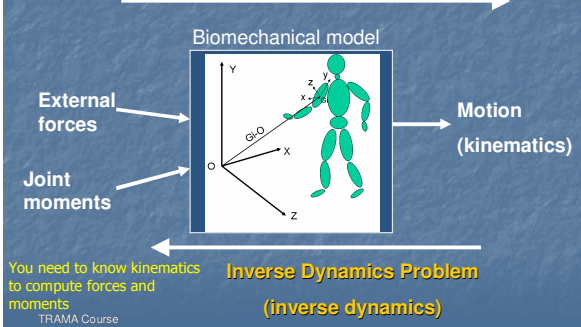
More information can be obtained through:

a) Dynamic system's modelling

b) Musculoskeletal modelling

Direct Dynamics Problem

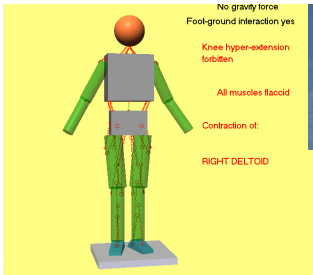
(forward dynamics)



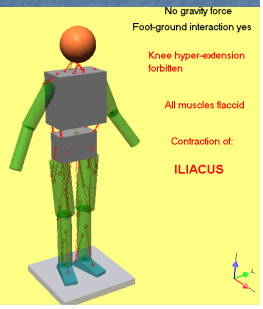
You need to know kinematics to compute forces and moments

Inverse Dynamics Problem

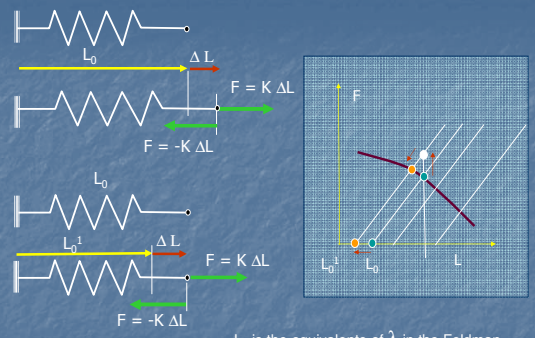
(inverse dynamics)



Example of movement simulation (Direct dynamics problem)

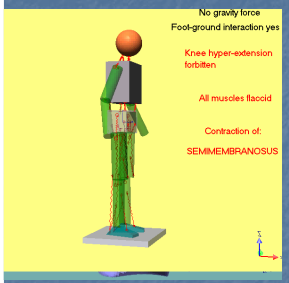


All body segments move as a consequence of a single force applied (coupled dynamcis)



L_0 is the equivalente of λ in the Feldman equilibrium point theory (λ is the threshold of the Tonic Stretch Reflex)

Pelvis fixed in space

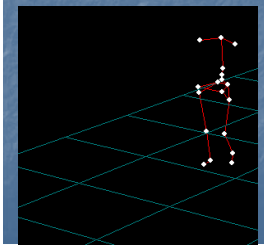


Foot fixed on the floor

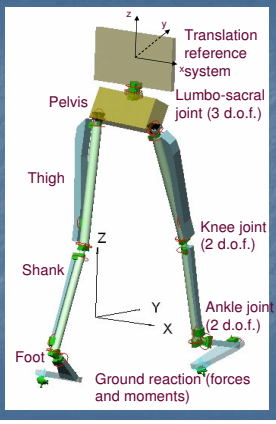
Dynamic models can be used to simulate movement perturbations and/or

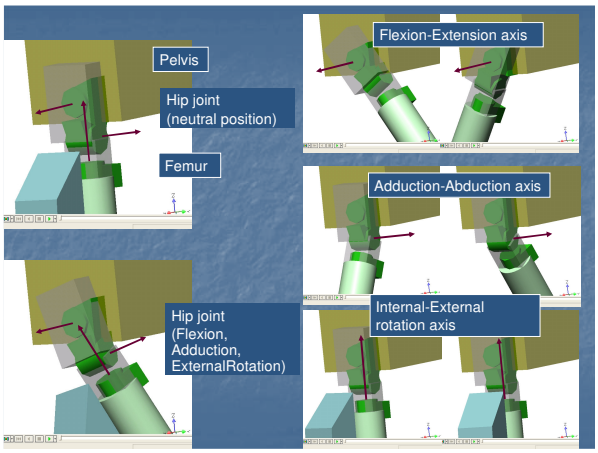
see the effects of changing the kinematics

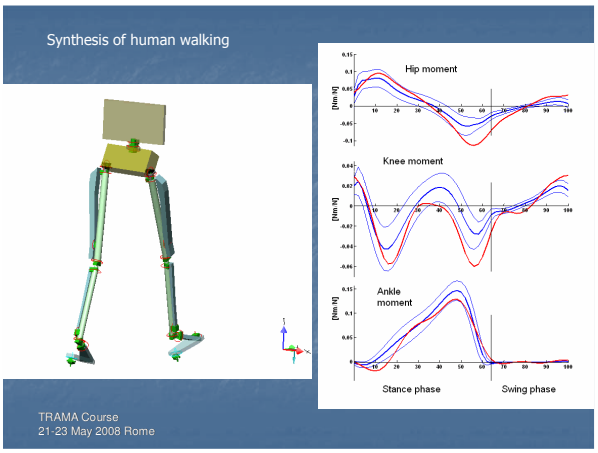
Data collection and processing system



Biomechanical model




Pelvis
Hip joint
(neutral position)
Femur
Hip joint
(Flexion,
Adduction,
ExternalRotation)
Flexion-Extension axis
Adduction-Abduction axis
Internal-External
rotation axis


Synthesis of human walking
Hip moment
Knee moment
Ankle
moment
Stance phase
Swing phase
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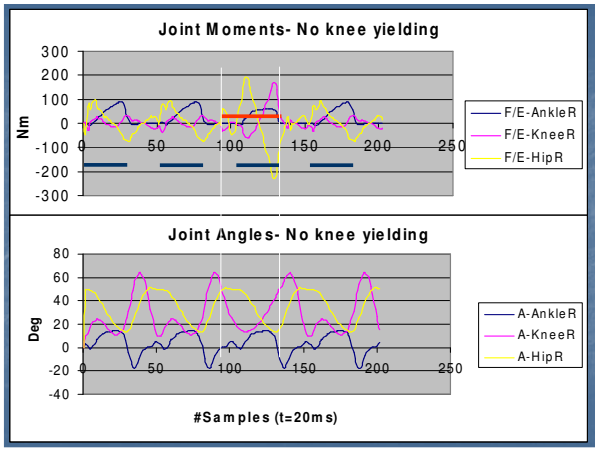
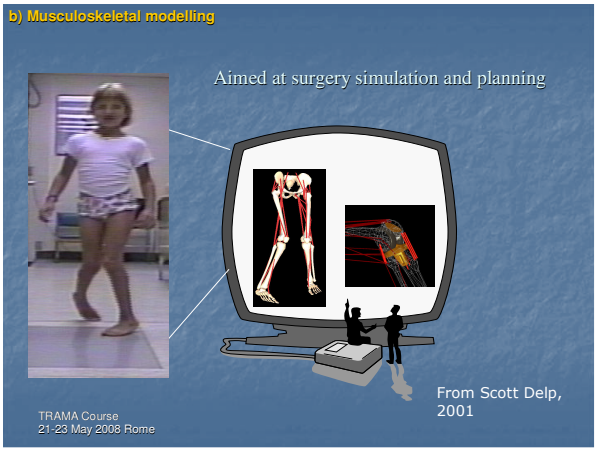

Joint Moments- No knee yielding
Nm
F/E-AnkleR
F/E-KneeR
F/E-HipR
Joint Angles- No knee yielding
Deg
A-AnkleR
A-KneeR
A-HipR
#Samples (t=20ms)


b) Musculoskeletal modelling
Aimed at surgery simulation and planning
From Scott Delp,
2001
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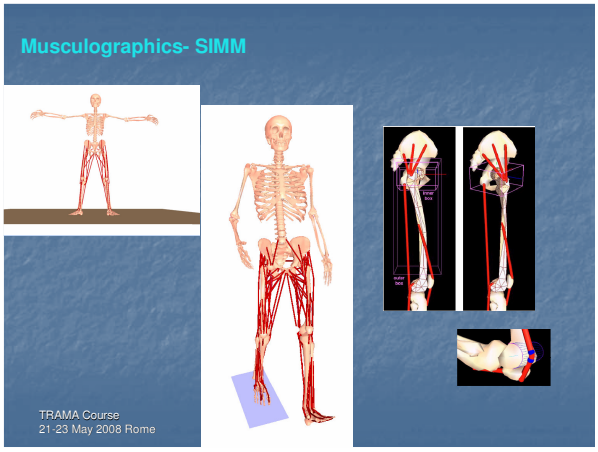
Musculographics- SIMM
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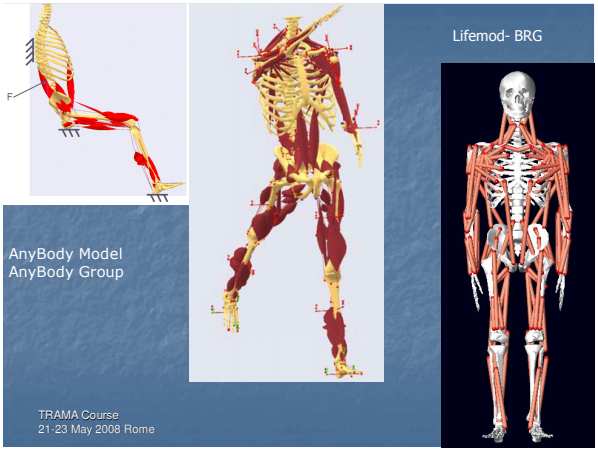
Lifemod- BRG
AnyBody Model
AnyBody Group
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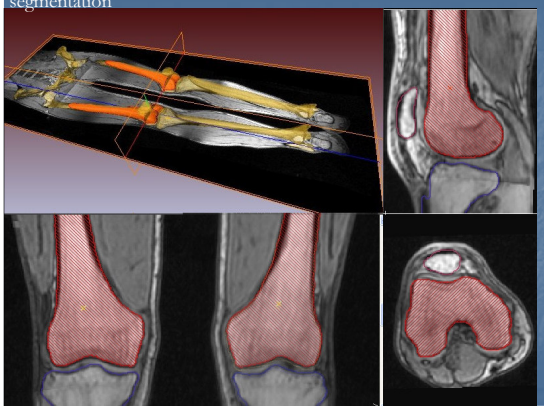
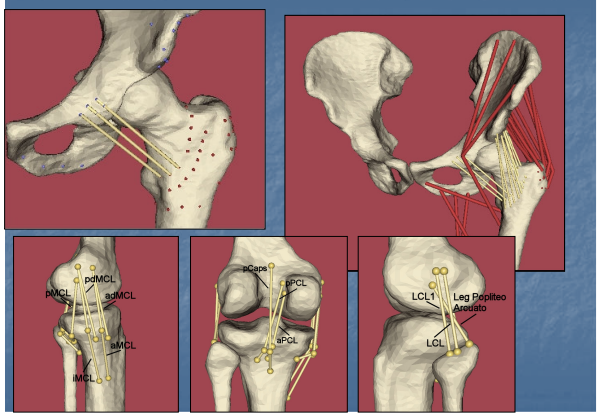
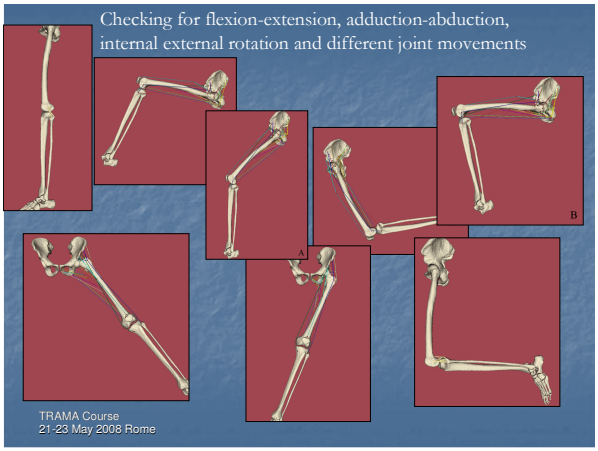
Anthopometric data collection from bio-images and segmentation



Soft tissue modelling: muscles and ligaments



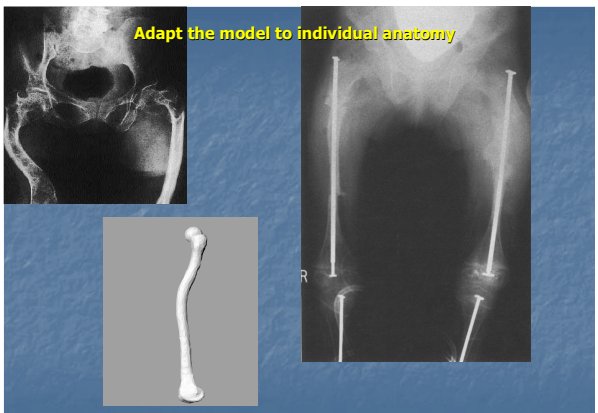
Checking for flexion-extension, adduction-abduction, internal external rotation and different joint movements

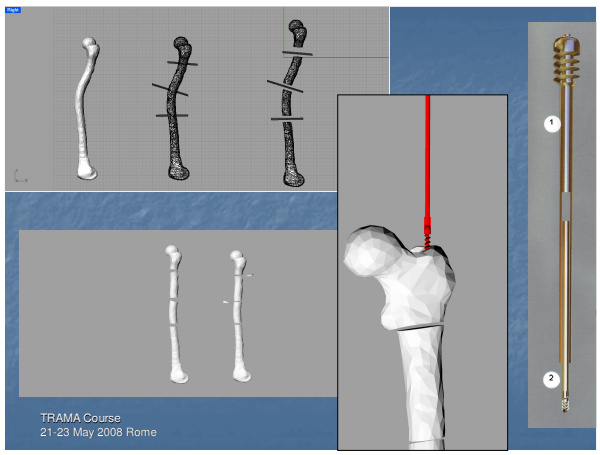


How to use musculoskeletal models

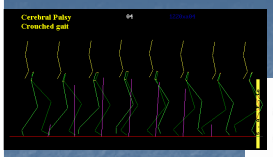
- Adapt the model to individual anatomy
- Input the actual joint kinematics
- Input joint limitations (from clinical tests): they correspond to limits of muscle lengthening
- Simulation of normal walking (virtual muscle length): we can see which muscles overcome their muscle lengthening limits

Adapt the model to individual anatomy

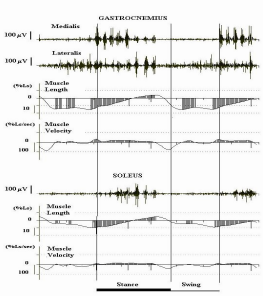




Input the actual joint kinematics

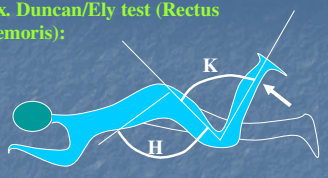


Example of Joint Analysis of EMG and Muscle Kinematics

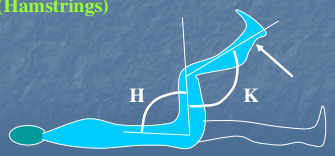


Analyse joint limitations

Ex. Duncan/Ely test (Rectus Femoris):

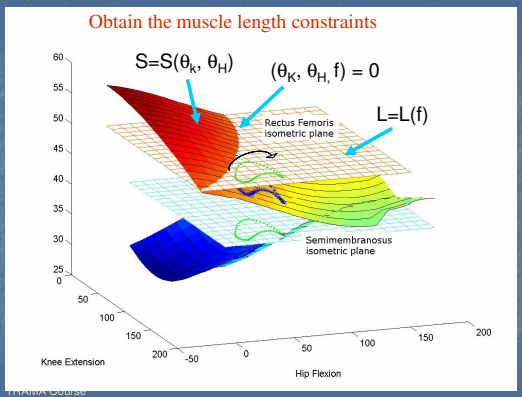


Ex. Max. Popliteal Angle (Hamstrings)

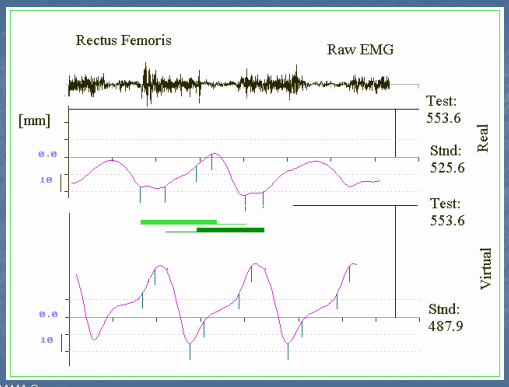


Input joint limitations into the model

Obtain the muscle length constraints



Simulate normal (virtual) walking



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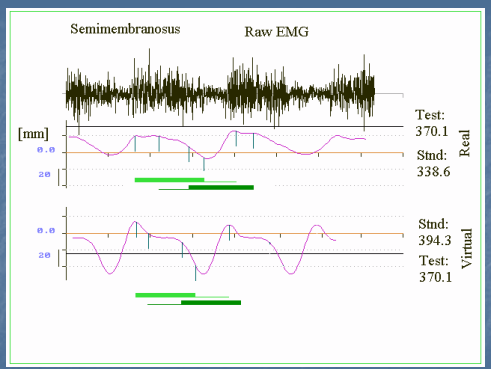
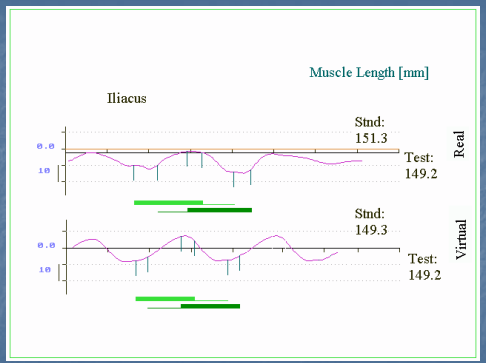


Simulate normal (virtual) walking



Analysis of 9 CP children (crouched)

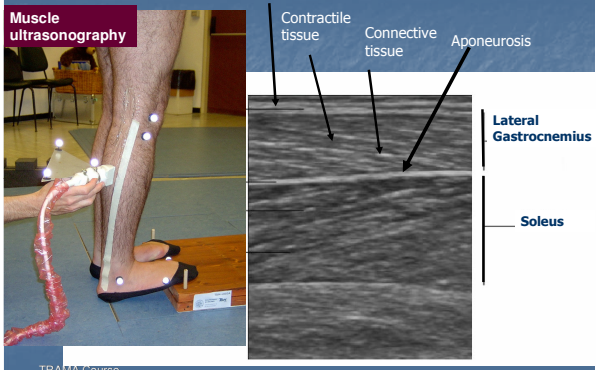
All values in mm

	Rectus Femoris			Semimembranosus			Iliacus		
Patient #	Max L (real)	Max L (virtual)	Max L (test)	Max L (real)	Max L (virtual)	Max L (test)	Max L (real)	Max L (virtual)	Max L (test)
1197XA	393,2	413,2	437	315,9	320	319,5	126,2	135,5	123,2
1227XA	524,1	550,3	577,9	431,1	444,7	441	166,7	183,3	177,0
1253XA	534,4	545,2	574,7	419,5	438,2	423,8	161,1	172,8	168
1220XA	527,8	519,1	553,6	365,1	410,6	370,1	150	156,9	149,2
1011XA	341,8	355	381,8	278,3	289,4	285,2	116,2	127,7	119,1
1196XA	567,1	573	606	448,3	478,6	472,5	175,8	185,2	175,1
1203XA	377	382,4	410,5	299	295,25	308,1	126	130,9	120,3
1243XA	436,2	448,2	469	307,9	335,9	325,3	137,9	145,3	142
1282XA	470,9	488,9	502,3	359,4	381,2	370,3	136,4	159,8	149,8
AV	463,6	475,0	501,4	358,2	377,0	365,4	144,0	155,2	147,0
SD	54,9	53,5	46,1	30,7	43,2	35,9	7,2	17,1	18,8

Musculoskeletal modelling can help identifying short muscles and plan for proper intervention, but….

- Muscle models must be improved (wrapping surfaces, joint kinematics)
- Antropometric data should be better estimated on the individual subjects
- Muscular and tendineus components should be better identified
- Clinical test measurements must be included in the procedure
- Motor control mechanisms and neural and muscular plasticity need to be better understood

Integration of bio-images into biomechanical model

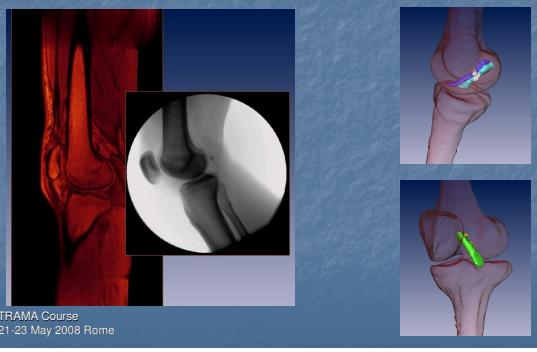


Fluoroscopy

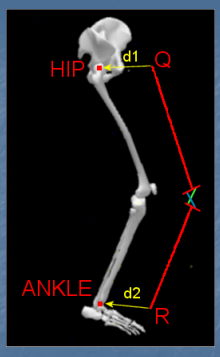
Advantages:
- Kinematic images
- Good resolution
- Low radiation doses

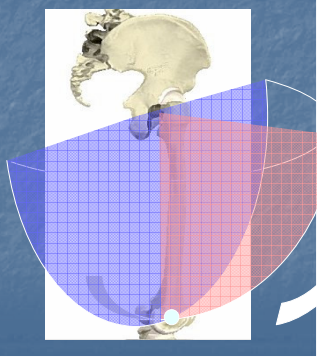
weak-points:
- Image distorsion
- Limited field of view

Identification of Ligaments

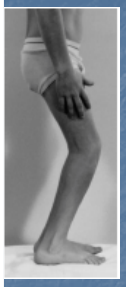


Optimal identification of joint centres and axes of rotation





The problem of Rotula Alta in CP children



Surgical intervention

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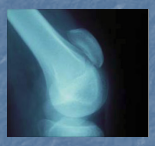

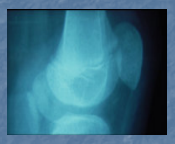

Models can help understanding the biomechanical effects of surgery

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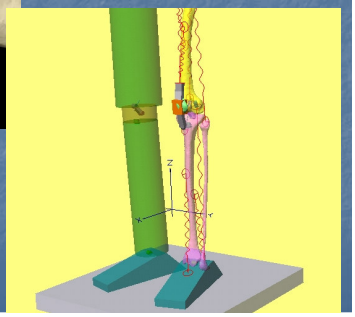
Thank You for Your attention



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